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INVESTIGATION OF CRANIOFACIAL MORPHOLOGICAL VARIATION AT SULLY (39SL4)

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Thesis

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for the degree of

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in Anthropology

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Investigation of Craniofacial Morphological Variation at Sully (39SL4)

Chairperson: Dr. Ashley H. McKeown

This study utilizes a theoretical framework of modern quantitative population genetics to identify factors contributing to the morphological variability between multiple, geographically distinct burial areas associated with the Sully village site (39LS4) in the Middle Missouri region of South Dakota. In particular three burial areas at Sully (A, D, and E) provide adequate samples for assessing intra-site variation. It has been a long-held belief that the observed morphological variability between burials areas is due to temporal sequencing; however, this explanation lacks hard craniometric and archaeological support. This study reassesses the assumption of temporal sequencing through the investigation of post marital residence patterns. The practice of matrilocality and village endogamy has been reported for the Arikara in ethnohistoric accounts; this pattern was investigated using a geometric morphometric approach in conjunction with standard statistical analyses. Three dimensional coordinate data from 20 craniofacial landmarks from 69 Sully burials attributed to the Extended Coalescent and 305 burials from Extended Coalescent and Post-Contact Coalescent cemeteries from Anton Rygh (39CA4), Mobridge (39WW1), Larson (39WW2), Black Widow Ridge (39ST203), Leavitt (39ST215), Cheyenne River (39ST1), and Indian Creek (39ST15) are examined to assess the factors contributing towards the phenotypic variation at Sully. The coordinate data were translated, rotated, and scaled via generalized Procrustes analysis permitting the inclusion of both males and females in the samples and fitted coordinates were subjected to principal component analysis. The resulting principal components were used as variables in three tests of homogeneity: Zhovotovskiy's F-ratio, Wishart's bootstrap, and a nonparametric bootstrap; these tests failed to detect the expected pattern of post marital residence, but found that the phenotypic variability at Sully is no greater than that of the temporally constricted village site Larson. Canonical variate analysis of the projected coordinates indicates that the inhabitants of the Sully site may have been patrilocal and participated in a complex system of mate exchange between Arikara villages. Evidence from this study suggests that the observed differences in morphology between the Sully burial areas can most likely be attributed to differential levels of inter-village admixture and not their temporal separation.

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Chapter 1: Introduction

One of the fundamental goals of bioarchaeology is the reconstruction of population history through the analysis of biological and cultural materials (Larsen, 2002). One of the methods through which this is accomplished is craniometric analysis; this allows for the investigation of inter and intra-group affinity, and provides information about gene flow (Relethford, 2004a), migration (Relethford, 2004b), and biological relatedness (Relethford, 1994). Through the application of craniometric analysis to questions of biological affinity, aspects of population history has been inferred for populations that lack a written history and has been given back to those populations (such as Native American groups) whose history has been skewed to further some political agenda.

The Arikara tribe of the Central Plains is one such Native American group that has been examined through traditional craniometric methods. These analyses have shown the geographical movement of the Arikara, level of biological affinity to neighboring tribes, and have aided in a relative timeline of site occupations prior to European accounts (Jantz, 1973, 1977; Jantz et al., 1981; Key, 1983; McKeown, 2000; McKeown and Jantz, 2005). Of all the known Arikara village sites, Sully (39SL4) has shown to misclassify with non-Arikara groups and it is believed that there may be non-Arikara components present at the site, as such, it stands out as not having a collective reality (Jantz et al., 1981) and remains a site of interest to anthropologists.

Sully is unique among Arikara villages: it was unfortified, contained multiple ceremonial lodges, and five geographically distinct burial areas. The primary debate involving this site is whether the burial sites are associated with multiple occupation periods, and are therefore

temporally ordered, or if the cemeteries were used contemporaneously by multiple clans within the village. This issue has been investigated using grave good frequencies (Rathbun, 1965), traditional craniometrics (Owsley and Jantz, 1978; Key, 1983), and geometric morphometry (McKeown and Jantz, 2005; Agosto and McKeown, 2012). These studies have yielded conflicting results: Rathbun (1965) and Agosto and McKeown (2012) suggest contemporaneous usage of the burial areas, whereas Owsley and Jantz (1978) and Key (1983), suggest the burial areas are temporally spaced. Due to the lack of agreement between studies, further research needs to be performed.

The current research project is designed to address the reason for multiple cemeteries at Sully through the examination of post marital residence patterns. Testing for a known pattern of post marital residency for the Arikara at Sully will offer insight into the factors contributing to the morphological variability between the Sully burial areas, the effects of microevolutionary processes on craniofacial morphology, and the contemporaneity of the burial areas. If the expected pattern of post marital residency is not detected at Sully, then other factors that would affect craniofacial morphology between the burial areas, such as admixture with nearby, contemporaneous villages, will be explored. This is a new avenue of investigating population structure within Sully or any other Arikara village and has potential to offer many insights into this population.

This research is guided by a theoretical framework of modern quantitative population genetics. This theoretical line has been applied to problems regarding population history, migration patterns, inferring kinship ties, biological diversity, and microevolutionary changes within a population (Larsen, 1997; Mielke et al., 2011). Based on the principles outlined by

these theories, a single research hypothesis is proposed. This hypothesis states that the craniofacial morphological variation between males and females at Sully is significantly different, with males displaying greater variation than females, consistent with village endogamy, clan exogamy, and matrilocal post marital residence.

Testing of the research hypothesis and fulfilling the goals of this research will be accomplished through the application of geometric morphometric and standard multivariate analyses to three dimensional coordinate data observed on crania from Sully and several nearby, contemporaneous Arikara villages. Coordinate data was chosen because of its utility in preserving all relationships between the landmarks (Slice, 2005, 2007) and ability to identify subtle variations in morphology between closely related groups (McKeown and Jantz, 2005). Geometric morphometric methods also allows for the removal of size so that the variables contain only information about shape. Results from standard statistical procedures on the fitted points will lead to a better understanding of the observed underlying morphological differences between these Arikara groups and the microevolutionary forces behind them.

Chapter 2: Literature Review

It has been long understood by physical anthropologists that cultural practices can have a distinguishable effect on biology; recognition of biosocial patterns can illuminate several aspects of past life ways. In a population with a known practice of post-marital residency, this pattern should be distinguishable if the biological samples are contemporaneous. It is under this presumption that a test of contemporaneity of the Sully burial areas will be undertaken.

This analysis requires an understanding of the utility of the analysis of craniofacial morphological variation, Arikara social organization, previous studies of intra-site variation at Sully, and the role of genetically controlled phenotypic traits in studies focusing on post-marital residency. A review of these concepts and studies is necessary to understanding the multi-component nature of this study.

Craniometric Analysis

A long standing assumption by early anthropologists was that skeletal, specifically cranial data could be used to infer biological relatedness between groups of people. The earliest of these studies employed the frequency of non-metric traits and measured cranial indices to answer questions about human biological variation, but these methods were found to be too subjective and prone to observer error. The 1950's brought about a paradigm shift in the field of physical anthropology; no longer were mere descriptions suitable as the basis for analysis, instead focus was placed on the theories that could explain observed phenomenon (Washburn, 1951) and much of the adopted theory was related to micro-evolutionary processes and how they affect morphology. Early studies focused on inter-population, intra-

population, and intra-site variation to illustrate the relationship between genetic factors and craniofacial morphology, and their utility for observing micro-evolutionary processes.

An early attempt to assess the effects of gene flow, a micro-evolutionary mechanism, on cranial morphology by Jantz (1973) compared Arikara, Mandan, and British White crania. This study found higher misclassification rates of historic Arikara in comparison to prehistoric Arikara, and that the morphological changes are regular and have a temporal pattern. The explanation used to describe this phenomenon is that the changes in cranial morphology through time are the result of gene flow with the Mandan and British. This was one of the earliest attempts to apply craniometric data to genetic information to assess evolutionary change.

A later study by Jantz (1977) compared Arikara crania with those of neighboring Central and Northern Plains groups. The results of this study found morphological change through time in the Arikara crania and that the morphology of the Arikara crania is similar to those groups that are both contemporaneous and in close geographic proximity. The explanation for this phenomenon is that there was considerable gene flow occurring between the Arikara, Mandan, Pawnee, and Central Plains Traditions. A similar study was performed by McKeown (2000) using only Arikara samples and geometric morphometry; this study yielded similar results to Jantz (1977).

Empirical evidence from studies such as the ones discussed has been used to show that there is a relationship between cranial morphology and genetics. More concrete evidence for this relationship was found in a study by Relethford (1994). This study compared patterns of craniometric variation and genetic variation and found that they mimic each other by showing

10% of the total variance was between groups and that the other 90% of variation was within a single group. This implies that craniometric variation can be used to discern patterns of genetic similarity in problems of population structure. This concept was later used to test theories about gene flow and the isolation by distance model (Relethford, 2004a) and look at the affect migration has on cranial morphology (Relethford, 2004b). Results from both studies followed what would be expected if genetic material was the primary data source; lending strength to the justification of using craniometric data in lieu of molecular data.

Further testing by Smith (2009) investigated the regions of the cranium that were under a stronger genetic influence and which areas would be more vulnerable to environmental factors. Although there is a level of genetic control over all aspects of craniofacial morphology, Smith (2009) found that the cranial vault was more sensitive to environmental changes and the upper face, basicranium, and temporal regions best reflected molecular distances. This study concluded that if molecular data was unavailable, then cranial data, especially from aforementioned regions, was an appropriate substitute.

The assumptions of early anthropologists were correct: craniofacial data can be used to investigate relationships between differing populations of humans. Through the studies of later researchers, this assumption was legitimized in the eyes of the greater scientific community and the depth of the relationship between genetics and morphology was uncovered. The application of morphometry to craniometrics is now the standard in anthropological research concerning biological relatedness and variation.

Morphometry

Simply stated, morphometrics is the study of form: its variances, between group differences, and association with extrinsic factors (Slice, 2007); it is the fusion of biology and geometry (Bookstein, 1982). Morphometrics was developed as a multivariate statistical method to rigorously address questions concerning patterns of variation within and between groups, patterns of growth, underlying reasons for observed differences, and homology (Slice, 2007). Morphometry has proven to be an extremely useful tool for both biologists and anthropologists, as it is a reliable analytical method to explain observed phenomenon in the natural world.

Although morphometry can be applied to any biological structure, in anthropology it has been most commonly applied to the cranium. Through its application to craniometry, researchers have investigated patterns of human variation (Howells, 1973; Relethford, 1994, 2004a), the emergence of modern humans (Relethford, 1995; Relethford and Harpending, 1995), and the effects of microevolutionary processes on morphology (Jantz, 1973, 1977; Relethford, 1997; McKeown, 2000). Studies using morphometry as a basis for analysis have been found to have more reliable and repeatable results.

Morphometric analysis employs quantitative methods and does not rely on subjective descriptions of traits as a data source; instead this approach uses continuous distributions of the phenotypic or genotypic expression. There are two primary avenues of analysis: traditional morphometrics and geometric morphometrics.

Traditional morphometrics is the most commonly used form of analysis in anthropology. It consists of using inter-landmark distances, angles, and distance ratios taken from the cranium

to extract information of morphological change and interpret biological processes that may have caused the observed differences (Slice, 2007). This is the earliest method employed by anthropologists to both collect and analyze cranial data. This form of data is collected with calipers, rulers, and other specialized devices from well-defined landmarks on the cranium. The main advantage to this type of data is that it is independent of orientation and position (Slice, 2005).

Although it has been shown to be a reliable and accurate method, there are some inherent issues with traditional morphometry. Due to the nature of inter-landmark distances, much information about the shape of the structure under analysis is lost; there is no information embedded in the data that accounts for the position of landmarks in relation to one another (Slice, 2005). The addition of inter-landmark angles is one way to overcome this disadvantage, however, their inclusion in the analysis may impede the application of multivariate statistics (Slice, 2005). These issues do not prevent valid research from being performed, but limits analyses to basic large-scale shifts in morphology.

Geometric morphometry has origins in biology, and began to be utilized in anthropology in the early 1990's. The goal of this method is the same as traditional morphometrics, but coordinate data captures information about shape and size of the geometric form in either two or three dimensions. Geometric morphometrics is able to capture more in-depth information about the shape and size of the form in question (the cranium in the case of this and most anthropological analyses) and can be translated into traditional craniometric values as well (Slice, 2007). Cartesian coordinate data is able to retain all relationships between the

landmarks captured and is, therefore, able to better illustrate the nuances of shape differences and change than traditional morphometry (Slice, 2005).

Ross et al. (1999) performed one of the earliest comparisons between traditional and geometric morphometry. Analyses using both traditional craniometry and geometric morphometry were performed using the same samples to test the ability of the two data sources to discriminate between populations. It was found that both data types yield similar results when performing inter-population analyses. However, it was shown that geometric morphometry is able to provide specific information regarding the location of morphological variation; something which is absent in traditional methods.

Research by McKeown and Jantz (2005) compared traditional craniometric data with Cartesian coordinates to test their utility in biological distance studies on the intra-population level; data from 11 components of 8 Arikara sites and both geometric morphometric and traditional morphometric statistical analyses were performed to generate biological distance matrices. Like in the study by Ross et al. (1999), both data types produced comparable results, however, the results derived from the coordinate data displayed stronger statistical relationships. Overall, the coordinate data was able to more effectively discriminate between sub-groups of the same population and identify morphological differences that were not apparent in the traditional craniometric analysis.

Its ability to detect subtle nuances in morphological variance is the major advantage geometric morphometry has over traditional methods. However, this methodology is not without its set of issues: coordinate data is reliant on orientation and each configuration resides in its own plane based on arbitrary axes (Slice, 2005). These issues are readily overcome

through the application of a generalized Procrustes analysis that translates, rotates, and scales coordinate data without introducing any bias into the data (Slice, 2001). A more thorough discussion of this matter can be found in the Methods section.

Both forms of analysis have been shown to be appropriate for all issues concerning morphometrics, however, it has been demonstrated that geometric morphometrics is able to produce more robust results for biodistance studies and exhibit more detailed variance in morphology. The application of geometric morphometrics to an investigation of post-marital living patterns within a village site may be able to detect subtle, yet significant, trends in morphology that the less sensitive traditional morphometrics may miss. It is because of its utility in identifying and visually depicting nuances in morphological variation within a population that geometric morphometrics will be utilized in this study.

Arikara Society

The Arikara of the protohistoric and historic periods were a Caddoan speaking group of horticulturalists that lived in the Middle Missouri Region of the Central Plains during the Coalescent Tradition; a timeline of the Coalescent Tradition can be found in Appendix A. This tribe was derived from the Pawnee (Denig, 1961; Carlson, 1998; Parks, 2001) of Nebraska. Similarities in language (Tabeau in Abel, 1939), oral histories (Dorsey, 1904), and mortuary practices (Ubelaker and Jantz, 1979), as well as acknowledged association by each tribe (Tabeau in Abel, 1939) are a testament to this relationship. The Arikara split from the Pawnee after AD 1400 (Blakeslee, 1981) and migrated north along the Missouri River into the territory of the Mandan and Hidatsa; their route has been tracked using archaeological patterns, craniometrics,

and language distribution (Blakeslee, 1994). Residence in South Dakota continued until 1832 when American military aggression forced the Arikara to join with the Mandan in North Dakota (Johnson, 2007).

Arikara villages were located along the banks of the Missouri River in South Dakota. A typical village consisted of a large, central, ceremonial lodge, and a collection of earth lodges surrounded by a ditch and palisade (Parks, 2001). Fortification was more common in earlier sites that were pushing the northern border of the Arikara territory (Krause, 2001). During this time, warfare was more commonplace (Willey, 1990; Parks, 2001) and those villages on the forefront of enemy territory would be in need of greater means of protection against outside invaders. As time progressed and relations with their neighbors to the north became less tense, the practice of fortification became more infrequent.

Social Organization

Each village was semi-autonomous with a head chief and three to four sub-chiefs (Rogers, 1990); chieftainship was hereditary, but could also be achieved through an increase in social rank by gaining prestige (Rogers, 1990). Although birthright was not the only way to attain the rank of chief, those who came by it through heredity were considered to be of a higher class of chief, and were the only ones eligible for election by the upper four classes of society to become the head chief of the Arikara (Rogers, 1990). It was believed that those born into the status of chief had a connection to the divine, and their place was sanctioned by a heavenly power (Holder, 1970). Being a member of the oligarchy was one of the few secure stations in Arikara society, others were more permeable.

Arikara social organization was complex and stratified with five principal levels of social class. According to Gilmore (1928), the highest social class was reserved for the chiefs, primarily the head chief, his sub-chiefs, and each village chief. These individuals were afforded special considerations within society and spoke a slightly different dialect of the language than the non-elites. The second level of social rank was reserved primarily for the men and women who held positions as priests and doctors. Men who received war honors comprised the third class, while men who were considered honorable soldiers made up the fourth level (Gilmore, 1928). The lowest level of Arikara social class consisted of the rest of the society, which was a majority of the population. Boundaries between the lower four classes were fairly permeable (Orser and Owsley, 1982) and one's rank in society could be improved through acts of valor and resource regulation (Holder, 1958).

This social structure had the most impact on the lives of the men in Arikara society (Holder, 1970); women typically did not hold influential positions. Instead, Arikara women functioned in a supportive role to their husbands and were a key factor to economic gain and stability.

Kinship Structure

Little more than a general outline is known of the kinship structure of the Arikara during the eighteenth and nineteenth centuries (Rogers, 1990). Through ethnohistoric accounts, it is known that the Arikara were a matrilineal society with matrilineal residence (Rogers, 1990; Parks, 2001) and spouse selection was endogamous within the village, but exogamous on the clan level (Orser and Owsley, 1982). With this custom in place, women would stay within the

clan or group in which they were born and men would relocate and live with a new clan upon marriage.

Land ownership belonged to the female heads of the household and inheritance stayed within the female line (Parks, 2001). Arikara women built the lodges, worked the land, and managed the crops; marriage to women who owned a lot of land, with the ability to grow surplus crops was advantageous because it allowed the family to participate in gifting practices and trade. Participation in both these practices, especially trade, were the quickest avenues for social climbing (Holder, 1958).

Trade

The Arikara were primary intermediaries in the inter-tribal trade network (Tabeau in Abel, 1939; Orser, 1984; Parks, 2001); the central locality of the Arikara's territory and their location on the Missouri River set them up to be a major trading hub. Unlike most other tribes that resided on the plains, the Arikara were semi-nomadic and relied heavily on horticulture as a means of subsistence. They grew a variety of beans, squash, corn, melons, sunflowers, and tobacco, which they traded with nomadic tribes for dried meats, decorative robes, exotic indigenous items, and Euro-American trade goods (Rogers, 1990; Parks, 2001). Due to their unique position, many Arikara villages were able to obtain Euro-American goods before contact took place (Rogers, 1990). These early items primarily consisted of objects of adornment such as beads; utilitarian items became more common once contact with European traders was made (Bass et al., 1971; Orser, 1984).

The Arikara's position as middle-men in the trade networks was reinforced after contact with European fur traders (Orser and Owsley, 1982; Orser, 1984) and participation in the fur

trade was lucrative for the Arikara. Simulations run by Orser and Zimmerman (1984) projects that saturation of Euro-American trade goods, both adornment and utilitarian items, within a village could occur within as short a time as 20 years after their introduction. This resulted in a weakening and blurring of the social boundaries as many lower class families were able to procure the means to quickly elevate themselves into a higher social class (Holder, 1958). As time progressed Euro-American trade items became more deeply entrenched in the Arikara way of life; not only were they integrated into everyday aspects of life, but into rituals and ceremonies as well (Rogers, 1990).

Mortuary Customs

Arikara mortuary practices were closely tied to their cosmology; they believed that the people were made of earth, and so, in death they must return to the earth (Maximilian, Prince of Wied-Neuwied in Witte and Gallagher, 2008). The Arikara were one of few Plains tribes that practiced direct interment of the dead as opposed to scaffold burials (Orser, 1983). Scaffolding of the dead was a rarity among the Arikara and may have occurred only in times when the ground was frozen and direct interment was not possible (Orser, 1980, 1983; Maximilian, Prince of Wied-Neuwied in Witte and Gallagher, 2008).

The dead were interred shortly after death in a grass-lined burial pit, typically in a flexed position with the head facing west (Bass, 1965; Orser, 1983). The face of the individual was painted red; they were dressed in their finest robes, and surrounded with items that would be necessary for their journey to the afterlife (Orser, 1983). It was customary to include only new items in the burial; this included both indigenous and Euro-American trade items (Thurman, 1984). Earlier sites included a higher propensity towards adornment items, as time progressed,

utilitarian items were interred with individuals as well (Orser, 1984). The inclusion of grave goods was customary for all individuals, regardless of social rank and differential treatment was typically reserved for chiefs (Orser, 1980).

Ethnohistoric information from a few traders and adventurers has given insight to the Arikara way of life, but cannot do justice to the complexities of Arikara society. The information available to researchers has invoked more questions than answers, and has led to many research projects focusing on numerous aspects of Arikara society and their interactions with neighboring tribes.

Studies of Temporal Variation at Sully

The Sully site (39SL4) is unique among the Arikara villages: it lacks fortification, has multiple ceremonial lodges, and contains five primary burial areas. It is the presence of four geographically discrete cemeteries that is the most distinguishing factor about Sully. Other Arikara sites, such as Mobridge, that contain multiple, distinct burial areas have experienced more than one occupational episode and the burial areas are temporally ordered. Originally it was presumed, based on the village excavations that the presence of four burial areas meant that Sully experienced multiple occupational episodes that would constitute early, middle, and late components (Johnson, 2007). Never the less, this may not be the case.

A study of the house pits by Johnson (2007) used a detrended correspondence analysis and descriptive rim sherd categories, a procedure typically used in inter-site analyses to investigate site stratigraphy and temporal ordering, was used to test the hypothesis of multiple occupations of Sully. Results from this test suggest that there are no well defined components

at Sully and that the site was most likely continuously occupied. The western part of the village seemed to be the earliest settled area with expansion to the east.

Continuous occupation of Sully only lends to the perplexity of the multiple burial areas. Studies focusing on this issue have not been able to come to a cohesive answer and results tend to fall within one of two categories: the cemeteries are temporally ordered or the cemeteries were used contemporaneously. Ascribing temporal order to the burial areas has been the most prevalent conclusion, but there has been no agreement as to how the sites are ordered. Contemporaneity of the burial areas is a newer finding, but is in need of further support before this conclusion is considered reality.

Studies Supporting Temporal Order

One of the earlier studies investigating temporal order of the burial areas at Sully was performed using traditional craniometrics and standard statistical analyses. Owsley and Jantz (1978) examined morphological variation of the crania from the different burial areas at Sully using a step-wise discriminant function analysis and they found statistically significant differences, indicating different morphology between the burial areas. Comparisons of the canonicals from three Arikara sites and one Central Plains sample of known relative dates identified the first canonical as representing morphological differences related to chronology as being the most important factor responsible for the observed variation. When Sully was included in the analysis, the burial sites displayed differential distribution along the canonical, indicating a temporal order. Based on these results, Owsley and Jantz (1978) concluded that Sully A and Sully B were late components and Sully D and Sully E were early.

The temporal order of the burial areas at Sully is contradicted by Key (1983). This study comprises an all-encompassing study of all Plains tribes from the Paleo-Indian through Historic periods. He utilized canonical correlation based on the principal components to demonstrate that time and geography was significantly related to the observed morphological variation. At the Sully site, this was combined with dendrochronology to order the burial areas; the results suggest that Sully A and Sully D are early La Roche sites, whereas Sully B and Sully E are later Le Beau sites (Key, 1983).

Temporal variation among Arikara sites, including Sully, has also been investigated using the more advanced geometric morphometry. McKeown and Jantz (2005) compared traditional craniometric and coordinate data taken from the same Arikara samples and samples from each data type were subjected to the same statistical analyses in order to evaluate the two different types of data. A secondary finding to this study suggests temporality to the burials areas at Sully. Based on the first two principal coordinate ordinations, it is suggested that Sully E should be considered an earlier La Roche similar to Sully A and Sully D.

There have been three key studies suggesting a temporal order to the burial areas at Sully, however, the results from these studies contradict; there has been no consensus as to which burial areas represent early, middle, or late components.

Studies Supporting Contemporaneous Use

Rathbun (1965) performed the first analysis testing for temporal variation of the Sully burial areas. This study focused on the grave good distribution as opposed to biological data. Fourteen different categories of materials were analyzed via frequency of presence for different qualifiers, such as age and sex, for each burial area and a chi-square test was applied

to test for significance. Individual item categories within the assemblage appeared to suggest temporal order, however, when all items were considered this order did not hold. Euro-American trade items are the key component in this analysis because the ratio of these items to indigenous items can be used as a relative dating method (Orser and Owsley, 1982). Each burial area at Sully had comparable percentages of all types of grave goods, both indigenous and Euro-American trade items (Rathbun, 1965). Since all burial areas had similar frequencies of Euro-American trade items, a temporal order cannot be established and instead suggests contemporaneity of the burial areas.

Contemporaneity of the burial areas has also been suggested through the use of cranial data as well. Agosto and McKeown (2012) used geometric morphometry in conjunction with standard statistical analyses and grave good distribution to test the hypothesis of temporal sequencing of the burial areas at Sully. Canonical variate analysis of the principal components indicates significant morphological variation between the Sully burial areas; however, when compared to the Extended Coalescent and Post-contact Coalescent samples from the Arikara site Mobridge in a linear regression analysis, temporally significant variation in morphology is made apparent, but temporal ordering of the sites was not supported. These findings were integrated with the artifact analysis of Billeck et al. (2005) and further supported contemporaneous use of the burial areas at Sully. Based on the findings of this research, it was suggested that the distinct burial areas at Sully may be due to co-habitation of Sully by multiple clans.

Due to the conflicting nature of the results from past research exploring temporality of the burial sites at Sully, further investigations are necessary. It is the goal of this thesis research

to test for temporality at Sully using an avenue that has yet to be explored: post-marital living patterns.

Post Marital Residency

Post-marital residency is a culturally defined system for social integration that dictates social interactions both within and among a society's regional community (Schillaci and Stojanowski, 2003). Post marital residency is the term used to describe the movement of people after marriage. Although there are many types of post marital residence, patrilocality and matrilocality are the two most common types (Tomczak and Powell, 2003) and the easiest patterns to discern for non-extant populations. Post marital residence patterns have received some attention in the literature of biological anthropology, yet this avenue of research has proven useful in demography studies.

Patterns of post marital residence were originally investigated using archaeological and ethnohistoric data. Archaeological studies have based predictions of post marital residence on the average living floor area for the typical dwelling in a society in conjunction with settlement pattern data and sex-based division of labor (Schillaci and Stojanowski, 2003). Research by Ember (1973) suggests that patrilocal societies have an average living floor area of less than 600 ft², while a larger square footage implies matrilocality. The size of the living space is most likely correlated to the type of activities that occurred there; this assumption has been combined with distributions of assumed sex-specific artifact classes to imply forms of social organization.

These approaches have been criticized as being too simplistic in their view of residency because they do not take into account the differences between a society's expected and actual behavior (Allen and Richardson, 1971) and people do not always behave in a projected manner.

Allen and Richardson (1971) present a thorough discussion of the issues with archaeological methodology for investigating post marital residence and conclude that unless there is a detailed historical record that such studies should be left to ethnographers. However, this solution is not exactly feasible for studies investigating non-extant populations.

The inclusion of osteological data into post marital residence research was first proposed by Lane and Sublett (1972). They suggest that the utilization of osteological data should be in conjunction with archaeological or cultural data; without a pre-established hypothesis about social organization, clusters of genetics are meaningless to problems of residency. Lane and Sublett (1972) emphasize that non-metric cranial traits can be used to look at genetic relationships among the sexes, but that these patterns do not cleanly equate to post marital residence practices. Due to the limited knowledge of genetic behavior in the 1970's, it was suggested that some other form of data, such as settlement patterns or ethnographies, should be the basis for presumed post marital residence with osteological data acting as a source of support. This was the first model of how genetic data could be used in studies of post marital residence and formed a basis for future research.

As the understanding of genetic behavior improved, so did population genetic theory. Konigsberg (1987) was the first to formalize models within a population genetic framework to explore intra-site variability and give the theoretical support genetic data required to stand alone in post marital residence research. Konigsberg (1987) proposed separating standardized variation into male and female sub-components to look at intra-site variation, and was able to demonstrate that differential levels of migration resulted in measurable differences in genetic and morphological variability. In terms of post marital residence research, this meant that

simple patterns in residency, like matrilocality and patrilocality, could be recognized. When working on intra-site analyses, the sex with the greater genetic variability is the more mobile sex, however, for inter-site analyses the mobile sex has less variability between groups (Konigsberg, 1987). This research also demonstrated that the homogenizing effect of multigenerational gene flow does not affect the phenotypic variability caused by post-marital living practices.

The models put forth by Konigsberg (1987) have been applied to several studies investigating post marital residence and kin group identification (Petersen, 2000; Schillaci and Stojanowski, 2002, 2003; Tomczak and Powell, 2003; Stojanowski, 2005; Petersen et al., 2006; Weisensee and Jantz, 2010). Stojanowski (2005) utilized metric dental traits to analyze the biosocial structure of graves at the San Pedro y San Pablo de Patale Mission cemetery; the primary focus of this study was to identify kin groups within the cemetery. In this study, a known practice of post marital residence was used to establish assumptions of relatedness between individuals and upon testing, was able to successfully use biological indicators to identify kin groups within the cemetery. Tomczak and Powell (2003) also utilized dental traits to investigate post marital residency patterns. Results from their study supported sex-based non-metric morphological variation in dentition could be accurately used to determine mobility of the sexes at the Windover site and therefor infer a practice of post marital residency.

Schillaci and Stojanowski (2002, 2003) integrated cranial and architectural data to reassess the assumed matrilocality pattern of post marital residency in prehistoric Puebloan communities of Chaco Canyon. A univariate F-test, determinate ratio analysis, and a step-wise discriminant analysis were used to test the levels of craniometric variability. The results of

these analyses were able to show that the post marital residence practice of the present day population was not the system used by the prehistoric Puebloan population.

The work by Schillaci and Stojanowski (2002, 2003) was reassessed by Weisensee and Jantz (2010) using the approach outlined by Petersen (2000). The results from this study support matrilineal post residency in multiple phases of Pecos Pueblo, particularly the early ones; this directly contradicts the findings of Schillaci and Stojanowski (2002, 2003). Overall, the Weisensee and Jantz's study demonstrates the utility of Petersen's (2000) method for comparing intra-site morphological variation in its relation to post marital residency.

Each of these studies has either been able to test a hypothesis regarding post marital residence and kin groups or use the patterns of genetically controlled phenotypic traits to infer practices of post marital residency and kin groups with success. Improved models and a better understanding of genetic behavior both within and between populations has changed the way studies of social organization and post marital residence have been conducted.

To date, there has been no application of post marital residence to issues of temporality either within or between populations using biological data. Most studies assume contemporaneity of the samples involved. However, if this aspect of the data is under debate, then testing for patterns of a known post marital residence practice should be able to confirm or reject contemporaneity; this premise is a keystone to the foundation of this research project. Through the application of population genetics models and known ethnohistoric data, this research proposes to use post marital residence to test the possible contemporaneity of the burial areas at Sully.

Chapter 3: Materials and Methods

This research operates under a theoretical framework of modern quantitative population genetics. This theoretical framework involves a series of models that are designed to explain and predict the behavior of genes and their phenotypic expression, both individually and on the population level (Mielke et al., 2011). These models have been applied to research regarding population history, migration patterns, inferring kinship ties, biological diversity, the displacement of individuals, and inferring microevolutionary change within a population, to name a few (Larsen, 1997; Mielke et al., 2011). It is in the effect of microevolutionary forces on gene frequencies and morphology that this research is most deeply rooted.

According to population genetics theory, gene frequencies are typically in equilibrium in a population, known as the Hardy-Weinberg Equilibrium and deviations from this state are caused by microevolutionary forces (Mielke et al., 2011). Each evolutionary force has a unique effect on gene frequencies; of relevance to this research is the manner in which admixture or gene flow affects the population. Gene flow has a homogenizing effect on gene frequencies, whereas its absence keeps populations genetically distinct (Cavalli-Sforza and Bodmer, 1971; Cavalli-Sforza et al., 1994; Mielke et al., 2011). This principle has been applied to the investigation of both inter and intra-site variation and has proven useful for the inferences of patterns of social organization and residence patterns.

Several models have been developed that illustrate how genes behave under the conditions caused by different patterns of residence. For the purpose of this study, the Island Model of Sexual Migration (Konigsberg, 1987) is applied; this model describes simple

relationships between sexual migration and population structure. According to this model, the more mobile sex will be more heterogeneous within a population and more homogenous across populations. Based on the level of variance, post marital residency patterns can be discerned; this can also be reversed so that if a population's practice of post marital residency is known, then the patterns of genetic variance can be predicted.

This concept has been utilized to test patterns of post marital residency that have been either described ethnohistorically or discerned through archaeological analysis (Schillaci and Stojanowski, 2002, 2003). These types of studies have three basic methodological assumptions that have been outline by Schillaci and Stojanowski (2003): accurate sex estimation of the sample, contemporaneity of the samples, and individuals within the burial areas were members of the population represented by those areas. Failure of the biological data to provide expected trends for populations where post marital residency is suspected, suggests an issue with either the presumed post marital residency practice or the underlying assumptions of the study.

Research Design

The purpose of this research is to examine the morphological variance of the individuals interred at the protohistoric Arikara village Sully (39SL4); individuals from cemeteries A, D, and E will be examined in order to discern whether or not the burial areas were used contemporaneously. In order to accomplish this, the morphological variation between the sexes will be examined to test for a known practice of post marital residency within Arikara society. The presence of this pattern will suggest contemporaneity of the burial areas.

Assessing levels of intra-site or sample variation was first proposed by Key and Jantz (1990); they attempted to identify levels of variation within a population by comparing it to a reference sample of known variability using a chi-square test. Later work by Petersen (2000) expanded upon this method and determined that the application of the F-test, parametric and nonparametric bootstraps were more appropriate for the application to skeletal samples because of their ability to handle small sample sizes and non-normal distributions. The method outlined by Petersen (2000) has been successfully used to test for patterns of post marital residency within populations and it is through this process that the phenotypic variation at Sully will be examined.

According to ethnohistoric accounts from the 1800s, the Arikara were a matrilocal society (Rogers, 1990; Parks, 2001) that practiced clan exogamy and village endogamy (Orser and Owsley, 1982). This would suggest that there would be little to no mate exchange outside of the village, in effect each village could be considered an isolated breeding population. Although the reality of mate choice probably does include individuals outside of the village, for the purpose of this study it will be assumed that the Arikara practiced strict village endogamy. Thus, mate choice would then consist of someone from another clan, but within the village.

Since males are the more mobile sex in a matrilocal society, it should be expected that the males at Sully would have higher levels of morphological variability within each burial area. Alternately, females at Sully should display low levels of variability within each burial area. These are the expected patterns of morphological variability provided the burial areas were used contemporaneously with a matrilocal pattern of post-marital residency. This research will

work under this theoretical framework and test the following null hypothesis and research hypothesis.

Research Hypothesis (H_R): The facial morphological variation between males and females at Sully is significantly different, with males displaying greater variation than females.

Significantly greater levels of variation present in males as opposed to females is indicative of a matrilineal pattern of post marital residency and would lend greater support for contemporaneity of the burial areas. Acceptance of this hypothesis is contingent upon rejection of the null hypothesis.

Null Hypothesis (H_0): The morphological variation between males and females at Sully is not significantly different. Similar levels of morphological variation between the males and females at Sully will result in failure to reject the null hypothesis. Upon acceptance of the null hypothesis, the viability of strict village endogamy and matrilineality will be explored by testing for evidence of gene flow with contemporaneous Arikara villages.

In order to test these hypotheses, coordinate data of 20 cranial landmarks taken from Sully and the other Arikara samples was observed using a three-dimensional digitizer (McKeown, 2000). The raw data was then fitted via a generalized Procrustes analysis so that standard statistical procedures could be employed. Principal component analysis was applied to reduce the dimensionality of the data. The principal components were then subjected to Zhivotovsky's F-ratio, Wishart's bootstrap, and a nonparametric bootstrap to test the morphological variability between the sexes at Sully. A canonical variate analysis was also run to determine the level of gene flow between Sully and contemporaneous Arikara villages. Relationships between the individuals interred at Sully were also assessed through a

comparison of grave good frequencies. Through these analyses, greater insight into the circumstances behind the multiple burial areas at Sully may be achieved.

Materials

To investigate morphological variability at Sully, samples from three of the burial areas at Sully (Sully A, Sully D, and Sully E) and five additional Arikara village components were utilized. Sully B was excluded from this study due to inadequate sample size and Sully C was excluded because it is uncertain whether the scaffold burials in this burial area are associated with the Sully site (Bass, 1965). Samples from Anton Rygh (39CA4), Larson (39WW2), an early and late component from Mobridge (39WW1), and an amalgamation of Bad River phase villages (39ST1, 39ST203, 39ST215, and 39ST15) were chosen for comparison with Sully based on sample size and temporal overlap with the occupation period at Sully. All sites have been attributed to the Arikara of the Middle Missouri region of South Dakota and were occupied during the Extended and Post-Contact Coalescent Traditions, 1400/1450-1650 AD and 1650-1862 AD respectively (Johnson, 2007; McKeown, 2013). Figure 1 provides a geographical distribution of the sampled sites.

All individuals in this study are adults that have been found to be both morphologically and culturally affiliated with the Arikara in order to discount any morphological differences that may be attributed to adolescent growth and population membership. Because accuracy of sex estimation is such an important aspect of this research, only individuals of identified sex have been included in this study; individuals of unknown or questioned sex were not included. Sex information was recorded by McKeown during initial data collection and verified with the National Museum of Natural History's report on the Arikara (Billeck et al., 2005). Table 1

provides a summary of sample name, approximate dates, and sample size broken down by sex; dates for each site have been adopted from Johnson (2007) and McKeown (2013).

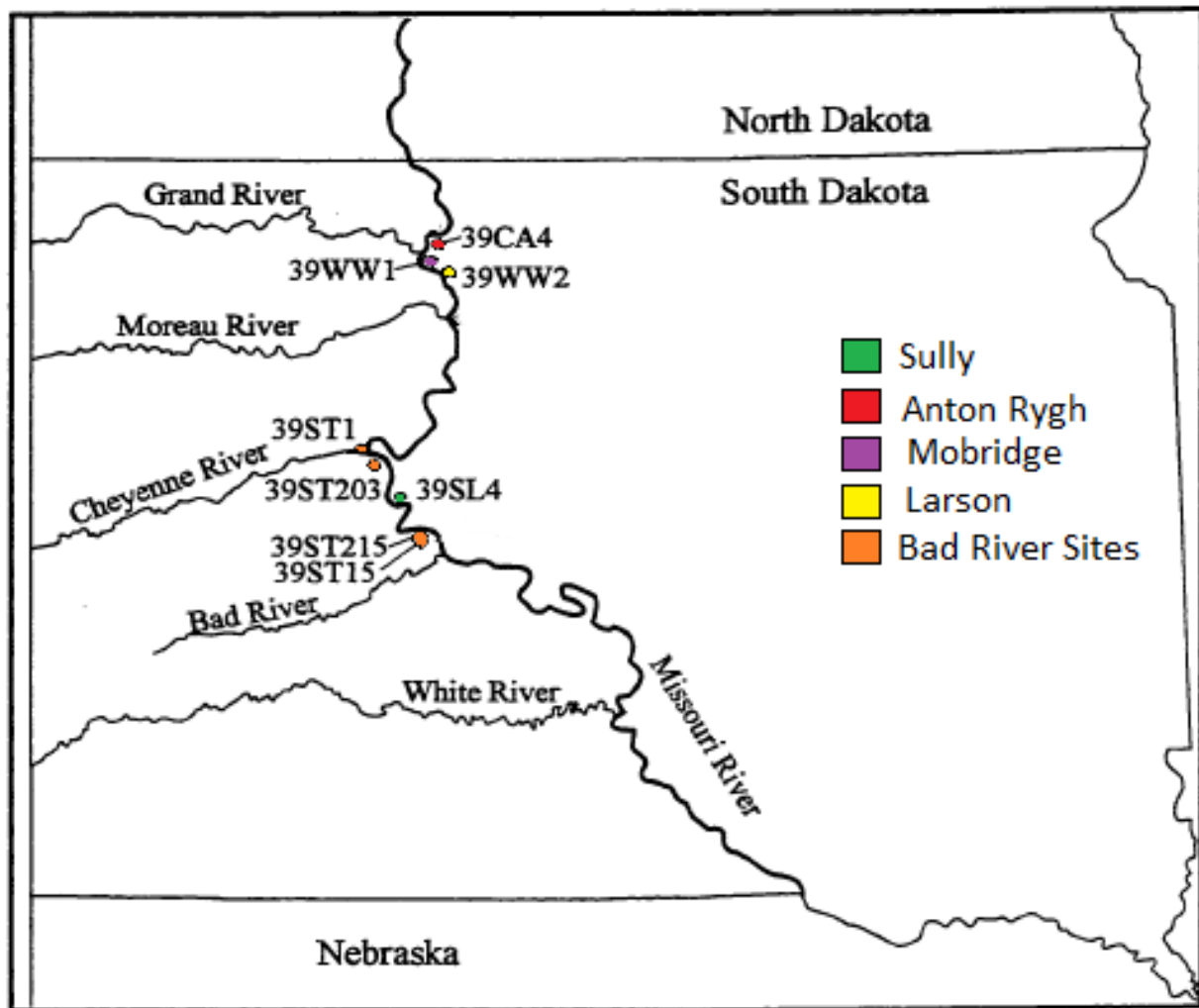


Figure 1. Geographical distribution of sampled sites; modified from McKeown, 2000, p46.

Table 1. List of Samples, Dates, and Sample Sizes

| Sample Name | Dates | Males | Females | Total |
|---------------------------|-----------|-------|---------|-------|
| Sully A | 1550-1650 | 13 | 8 | 21 |
| Sully D | 1550-1650 | 10 | 11 | 21 |
| Sully E | 1550-1650 | 17 | 10 | 27 |
| Anton Rygh | 1550-1600 | 14 | 12 | 26 |
| Mobridge F1/3 | 1550-1600 | 20 | 23 | 43 |
| Mobridge F2 | 1625-1750 | 50 | 23 | 73 |
| Larson | 1700-1725 | 63 | 71 | 134 |
| Bad River Amalgamation | 1675-1800 | 16 | 13 | 29 |

Dates for these sites have been adopted from Johnson (2007) and McKeown (2013).

Site Descriptions

Sully (39SL4)

The Sully site is a large, unfortified Arikara village site located on the left bank of the Missouri River near Pierre, South Dakota. It is one of the largest known Arikara sites and during the Extended Coalescent it contained at least 200 earth lodges, four ceremonial lodges, and four geographically distinct burial areas (Johnson, 1998). Archaeological investigations of the village suggest an occupation time from approximately AD 1550 – 1650 (Johnson, 2007).

Recovery efforts began in 1930 with the excavation of 30 burials led by Bowers and were resumed by W.M. Bass in 1957, 1958, and 1961 with the Smithsonian Institution River Basin Survey crews; Bass led an additional recovery effort with the University of Kansas field crew in 1962 (Bass, 1965; Jantz, 1972). Four distinct burial sites (designated Sully A, Sully B, Sully D, and Sully E) containing 566 individuals in 316 burial pits have been located and excavated at Sully; scattered remains associated with a scaffold burial have also been found near Sully and have been assigned the designation of Sully C (see Fig. 2). Due to sample size, only individuals from Sully A, Sully D, and Sully E have been included in this study.

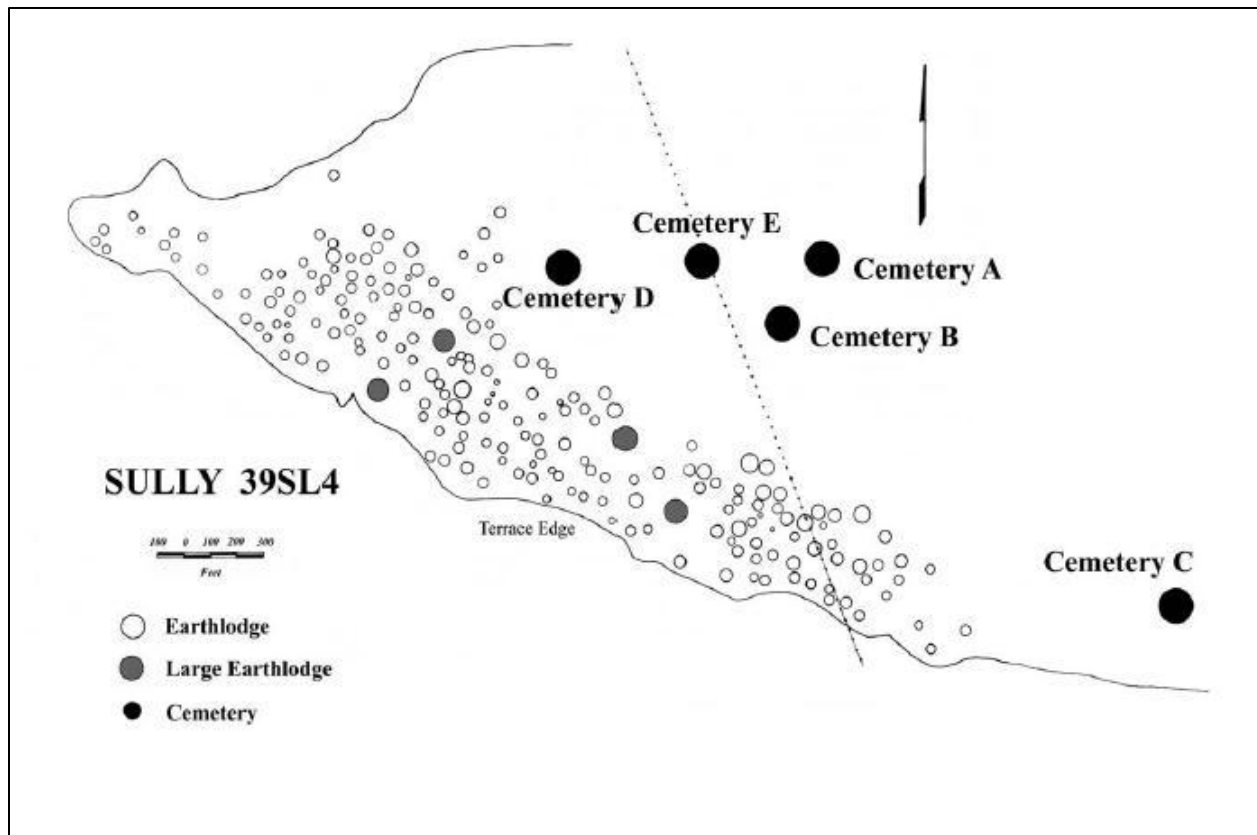


Figure 2. Map of Sully site from Billeck et al., 2005, p358.

Anton Rygh (39CA4)

Anton Rygh (39CA4) consists of a village and cemetery on the left bank of the Missouri River in the Grand-Moreau region. Extensive excavations by Bowers took place from 1959 to 1963 and in 1965 by a field crew from the University of Kansas. It is believed that there were four occupations at Rygh, with only the last occupation period containing Euro-American trade goods. Based on the lack of associated Euro-American trade items, burials from this site have been attributed to La Roche phase of the Extended Coalescent (Jantz, 1972).

Mobridge (39WW1)

This large, multicomponent site is located on the left bank of the Missouri River, northwest of Mobridge, South Dakota; it consists of a village and two cemeteries. Excavations

were conducted at this site by Stirling in 1923, University of Kansas field crews between 1968 and 1970, and by Ubelaker and Stewart in 1971 (McKeown, 2000). There are three distinct features at this site: Feature 1 is west of the village, Feature 2 is south of the village and Feature 3 is 100 yards south of Feature 1. Based on the distribution of Euro-American trade goods in the burials, it is believed that Features 1 and 3 represent early components from the Extended Coalescent, whereas Feature 2 is from the later Post-Contact Coalescent. This temporal order is supported craniometrically (Owsley et al., 1982).

The burials recovered from Stirling's excavation in 1923 have been under debate as to which feature they originate. These burials have been attributed to the Post-Contact Coalescent based on the presence of some Euro-American trade goods and have been grouped with Feature 2 in past studies using this data set (McKeown, 2000). Due to the question of the actual location of the Stirling burials, they have not been included in this study.

Larson (39WW2)

The Larson site, located on the left bank of the Missouri River, is comprised of an earthlodge village and associated cemetery. Human skeletal remains have been located both within the village area and cemetery; skeletal remains from the village were excavated by Bowers in 1964 and the cemetery burials were excavated by Bass with the University of Kansas field crew from 1966 to 1968 yielding over 700 individuals (Jantz, 1972). Due to the frequency of Euro-American trade goods, the cemetery burials have been attributed to the Post-Contact Coalescent. Individuals recovered from the village have not been included in this study.

Bad River Amalgamation

The Bad River sample is composed of a combination of individuals from four sites: Cheyenne River (39ST1), Indian Creek (39ST15), Black Widow Ridge (39ST203), and Leavitt (39ST215). All four sites are located on the right bank of the Missouri River in South Dakota and are the closest, geographically, to the Sully site. Black Widow Ridge and Indian Creek are earlier sites and are attributed to the Bad River 1 phase (1674-1740 AD), whereas Leavitt and Cheyenne River have been attributed to the later Bad River 2 phase (1740-1795 AD). Although the sites are temporally separated, individuals from these sites have been combined into a single sample. Due to their close proximity to Sully, their inclusion in the study was deemed important in order to investigate possible gene flow between the sites. Independently, the Bad River sites do not yield sufficient sample sizes for inclusion in this study and have therefore been aggregated. Preliminary tests performed by the author have shown that the aggregated Bad River sample has no more variation than a single component Arikara village sample and can act as a singular unit for this study; results of this test will follow in the Results and Discussion sections of this paper. Table 2 lists the site name, number, dates, and samples broken down by sex for the aggregated Bad River sample.

Table 2. List of Sites and Sample Sizes Comprising the Bad River Sample

| Site Name | Sit Number | Dates | Males | Females | Total |
|-------------------|------------|-----------|-------|---------|-------|
| Black Widow Ridge | 39ST203 | 1675-1740 | 2 | 1 | 3 |
| Indian Creek | 39ST15 | 1675-1740 | 1 | 1 | 2 |
| Leavitt | 39ST215 | 1740-1792 | 4 | 2 | 6 |
| Cheyenne River | 39ST1 | 1740-1795 | 9 | 9 | 18 |

Dates have been adopted from Johnson (2007).

Landmarks

For this research, craniofacial data will be used as a proxy for genetic data; the legitimacy of which has already been discussed. Three-dimensional coordinate data was taken from the Arikara collections housed at the Smithsonian Institution, National Museum of Natural History, and the Department of Anthropology, University of Tennessee, Knoxville. This data was collected by Dr. Ashley McKeown in the late 1990's using a laptop computer connected to a three-dimensional digitizer, MicroScribe-3DX. The collection protocol and NAGPRA status of the collections can be found in Appendix B.

Over 60 cranial landmarks were collected by Dr. McKeown, twenty of which are used for this study. See Table 3 for a list of the landmarks used and Figure 3 for their location on the skull, whereas a full description the landmarks, as described by Howells (1973), Moore-Jansen et al. (1994), and White et al. (2012), used can be found in Appendix C. Landmarks chosen for this study are concentrated on the facial region and selected for their ability to capture its form; this area of the cranium is more strongly controlled by genetics and resistant to environmental factors than the cranial vault (Smith 2009).

Table 3. List of Landmarks Employed

| | | | |
|-----------------------------|-----------------------------|-----------------------|----------------------|
| 1. Nasion | 6. L Zygomaxillare | 11. R Zygomaxillare | 16. Bregma |
| 2. L Dacryon | 7. R Dacryon | 12. L Alare | 17. L Pterion |
| 3. L Anterior Frontomalare | 8. R Anterior Frontomalare | 13. R Alare | 18. L Zygomatic Root |
| 4. L Posterior Frontomalare | 9. R Posterior Frontomalare | 14. L Frontotemporale | 19. R Zygomatic Root |
| 5. L Zygoorbitale | 10. R Zygoorbitale | 15. R Frontotemporale | 20. R Pterion |

Bookstein (1982, 1990) defines three types of landmarks. Type 1 landmarks are “recognizable points on boundaries between regions of distinct histology” (Bookstein, 1990,

p215); these typically consist of suture intersections or distinct boundaries. This landmark type is considered to be truly homologous and therefore more informative than the other two forms of landmarks (Bookstein, 1990). Bookstein (1990, p215) identifies Type 2 landmarks as “local geometric features of extended tissue boundaries”; although not as informative as Type 1 landmarks, they still contain useful biological information. Type 3 landmarks are the least informative of all the landmarks because they represent extremal points of a form and are used for maximum linear distances and are only informative about size (Bookstein, 1990). The landmarks in this study are comprised of Type 1 and Type 2 landmarks.

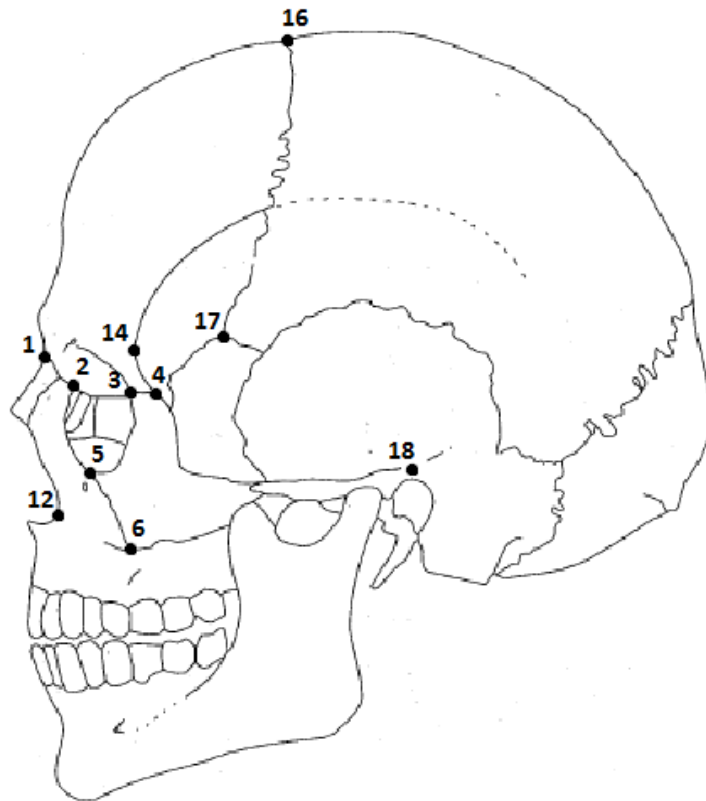


Figure 3. Left lateral view of cranium with visible landmarks labeled.

Analytical Methods

Investigating the morphological variability at Sully combines standard statistical procedures with geometric morphometry. For each landmark there are three Cartesian coordinates (x, y, and z), which capture the variation in cranial morphology. Geometric morphometry must be applied to the raw data before standard statistical tests can be employed; these methods were performed using MorphoJ v. 1.05c (Klingenberg, 2011), statistical software designed to work with coordinate data and create visualizations of the observed morphology encoded in the data. This program was used to perform a full Procrustes fit, a method of super-imposition that removes variation due to location, orientation, and size from the data without introducing bias (Slice, 2001; Rohlf, 2003), and generate a new covariance matrix prior to performing a Principal Component Analysis (PCA) and Canonical Variate Analysis (CVA).

When dealing with specimens that have object symmetry, such as the human cranium, MorphoJ separates the shape variation into categories of symmetric and asymmetric components; both of which are useful for investigating biological variation. The symmetrical component provides information that can be used to answer most questions of biological variation, whereas the asymmetrical component is used for more specialized analyses, such as “a measure of developmental instability in context such as hybridization” (Klingenberg, 2011, p534). All analyses performed in MorphoJ for the purpose of this study have been done so using the symmetric component.

After the raw data was subjected to the geometric morphometric analysis, the dimensionality of the data was reduced to a series of principal components. It is these principal

components that are employed in the tests of homogeneity and post marital residency tests. Although tests of homogeneity were developed by Key and Jantz (1990), it is upon the revision proposed by Peterson (2000) after which this analysis is modeled. Instead of using chi-square tests, Petersen (2000) proposes using the F-test and both parametric and nonparametric bootstraps; the calculations for these procedures are based on the determinants of the covariance matrices. Three analyses were performed: Zhivotovsky's F-ratio, Wishart's bootstrap, and a nonparametric bootstrap; 999 bootstraps were performed for this analysis to attain the 0.05 level of significance. These analyses were performed using the statistical package, R version 2.15.3 (R Core Team, 2013); scripts were provided by Dr. Hans Petersen of the University of Southern Denmark-Odense University and Dr. Lyle Konigsberg of the University of Illinois at Urbana-Champaign.

A test of homogeneity was run on the principal components from all individuals in the Sully and Larson samples with the Larson sample acting as the reference sample. Larson was chosen because it is temporally constrained, spanning an occupation of only 25 to 50 years (Johnson, 2007), and individuals from this site cluster tightly together in a CVA when compared to other Arikara sites (McKeown, 2000). The level of homogeneity between the sexes for the Sully site was compared, testing for both an overall matrilineal and patrilineal pattern of post marital residency for the site; females acted as the reference sample for the matrilineal test and males as the reference sample for the patrilineal test.

A test of homogeneity was also run on the amalgamated Bad River sample with Larson acting as the reference sample. This test was performed to examine the legitimacy of

aggregating individuals from four separate sites and two different temporal phases in Arikara culture history into a single sample.

The principal components from the Sully sample were used to test the variability between the sexes within each burial area. Since the level of morphological variability is expected to be greater in males, they will act as the hypothesis sample and the PC scores from the females will act as the reference sample. Due to the small sample sizes of each sex within the burial areas, the number of principal components used for the analysis will be limited to those that represent 90% of the total variation; this is a common criterion for determining how much variation to include in analyses (Holland, 2008). Provided the principal components are unable to yield intelligible results, the canonical scores derived from a CVA based on the projected coordinates of the Sully components will be used in the homogeneity tests. A p-value less than or equal to 0.05 will indicate significantly different amounts of variability between the sexes.

A canonical variate analysis based on the projected coordinates was applied to test for levels of gene flow between Sully and four other Arikara village components: Anton Rygh, Mobridge F1/3, Mobridge F2, and the Bad River agglomeration. The CVA was run using both site and sex as a classifier to distinguish differences between these components. The purpose of a CVA is to assess the morphological differences between previously defined groups to explore the greatest differences between them. A Mahalanobis distance matrix displaying the relative distance between group centroids was also produced, as well as significance tests for the distances between groups; significance is held to the level of 0.05 for this analysis.

Significance for the Mahalanobis distances was calculated using a permutation test. A permutation runs the analysis multiple times (10,000 times in this analysis) and reorders the cases each time; this is performed to account for any false significance that may be a result of the order that the cases were inputted into the statistical program (Hesterberg et al., 2005).

Geometric Morphometrics

Morphometrics is a suite of multivariate statistical analyses designed to investigate form; within biology it is primarily utilized to examine the average form and patterns of variation of some structure within a population and explore differences between groups (Slice, 2007). Traditionally this has been achieved through the use of inter-landmark distances, angles, or distance ratios taken directly from the specimen (Rohlf, 1990; Slice, 2007). Although traditional methods have been able to show biologically meaningful relationships, they retain size information within the data, and fail to fully capture the spatial orientation of the landmarks, thereby omitting information about the shape of the object (Slice, 2005, 2007). This short-coming of traditional morphometrics can be remedied through the use of Cartesian coordinate data in geometric morphometry.

Geometric morphometry utilizes either two or three-dimensional coordinate (landmark) data, which is comprised of a set of coordinates, taken from homologous landmarks on specimens from a population. This form of data collection allows for the capture and preservation of all information relating to geometric form (Slice, 2001), and can be converted into traditional morphometric data forms. By preserving all possible relationships between the points, collection of Cartesian coordinates also allows for all possible mathematical computations to be performed with the data (Rohlf et al., 1996). The retention of all

information related to shape allows for more accurate and stronger statistical relationships to be derived from the data, this is especially true in the study of human craniofacial morphology (Hennessy and Stringer, 2002; McKeown and Jantz, 2005). The high degree of information on biological form retained is a major advantage to using geometric morphometry.

Despite its advantages, there are some inherent issues imbedded in the data that are a direct result of the data collection processes in geometric morphometry. In order to collect data in coordinate form, arbitrary axes must be created for each specimen; this gives the coordinates for each landmark on the specimen meaningful orientation in relation to each other (Slice, 2005). This process allows for the full retention of geometric form, but also creates a separate plane (different spaces) for each specimen and, like traditional morphometrics, embeds size information into the data as well. These factors make the raw coordinate data unfit for use in standard statistical analyses and must be remedied before any analyses can be performed. Although there are multiple methods designed to complete this task, only the generalized Procrustes analysis does so without introducing any bias into the data (Slice, 2001).

Generalized Procrustes Analysis

A full generalized Procrustes analysis (GPA) is a statistically powerful superimposition method that removes location, rotation, and size from the data while retaining all variables related to shape (Slice, 2001). By isolating the variables associated with shape, true differences in variation between populations can be observed. The application of this method prepares raw coordinate data so that it is compatible for use with standard statistical analyses; this is accomplished through the translation, rotation, and scaling of the raw data (Slice, 1996).

The first step in GPA is translation; this takes all the specimen configurations from the sample dataset from their original, separate spaces and places them into a shared space where they are all superimposed and centered on a common origin (Rohlf et al., 1996). The configurations are then rotated into a common orientation by reducing the sum of the squared differences between homologous landmarks for all samples (Slice, 1996). Once all the configurations have been rotated, they are scaled to a unit centroid size (Rohlf et al., 1996; Slice, 1996), thus extracting size information from the data, and all data coordinates are correlated to points in shape space (Rohlf et al., 1996). It is within shape space that a common reference shape, or mean shape, is calculated.

Shape space, more commonly known as Kendall's shape space, is a non-Euclidean, sphere-like space where three points for each two-dimensional configuration corresponds to a point on the sphere's surface (Rohlf et al., 1996). As the dimensionality of the configurations increases, so does the complexity of Kendall's shape space; due to the nature of this space, geometric morphometric analyses cannot be performed there and the points are projected onto a tangent hemispherical space of radius one (Slice, 2001). Like Kendall's shape space, the surface of the hyper-hemisphere is curved and relies on non-Euclidean distance measures; therefore, statistical analyses cannot be performed within it (Slice, 2001). To account for this, each configuration is projected into a linear, Euclidean space tangent to the shape space (Slice, 2001). Once the points are projected, standard statistical procedures can be performed.

Standard Statistical Procedures

Principal Component Analysis

Principal component analysis (PCA) is a multivariate statistical method that seeks to identify meaningful sources of variation within a dataset. For a linear combination of variables, this maximizes the within sample variance and results in a maximal spread of the observations along a set of axes (Rencher, 2002). The overall idea of PCA is to reduce the dimensionality of a dataset while retaining as much information about the possible variation within it (Reyment et al., 1984; Jolliffe, 2002; Holland, 2008). PCA treats all individuals as a single population and when working with data related to an organism's proportions, extracts information about biological variation in a sequence of most to least influential on morphology, or a set of PC scores (Reyment et al., 1984). Principal component scores can be used to investigate morphological variation both within and between groups or can be used as variables in other multivariate statistical procedures.

Canonical Variate Analysis

Canonical variate analysis (CVA) is a technique used to assess the morphological differences between a number of previously defined groups or populations. The CVA is applied to the projected coordinates, producing results that allow for the morphological relationships between samples to be accurately interpreted. These analyses create correlations that are indicative of the relationships apparent in the canonical variates. The relationships between groups are simultaneously explored to maximize the separation between each group based on the variation within each population (Reyment et al., 1984). This analysis is focused on the

differences between groups and provides an output separating the data by the computed variation.

Mahalanobis Distance

Mahalanobis distance provides a quantitative means of evaluating morphological similarities and differences between groups (Van Vark and Schaafsma, 1992). Mahalanobis distance is derived from the pooled variance and covariance matrices of all sampled groups and works to quantify the differences between their centroids. A smaller distance indicates more similarity between samples, whereas a larger distance signifies a greater level of variation. These distances are relative to the samples involved and can change with the inclusion or exclusion of sample groups (Zelditch et al., 2004). Due to the relative nature of the produced distances, a test of significance is necessary to infer any meaningful relationships between the groups involved.

A permutation test is a test of significance that runs the analysis multiple times (10,000 times in this analysis) and reorders the cases each time; this accounts for any false significance that may be a result of the order that the cases were inputted into the statistical program (Hesterberg et al., 2005). Permutation tests work under the premise that the null hypothesis of no difference is true and present the significance of any differences between the cases in the form of a p-value. A p-value is the probability of observing a test statistic either extreme as or more extreme than what was observed if the null hypothesis is true. A small p-value suggests that the observation has a real effect on the population and acts as evidence against the null hypothesis (Hesterberg et al., 2005).

Tests of Homogeneity

Three methods are utilized to analyze the levels of homogeneity within the sample population against a reference population: Zhivotovsky's F-ratio, Wishart's bootstrap, and a nonparametric bootstrap. Each analysis is based on the ratios of determinants of covariance matrices, $|H|/|W|$, where H and W represent the covariance matrices of the hypothesis and reference samples respectively (Petersen, 2000). In essence, these analyses are designed to test whether or not the sample population has more intrinsic variation than the reference population. When applied the issues of post marital residency, this translates into whether one sex is more variable than the other. A basic explanation of the three tests will be presented here, for a more thorough, mathematically based explanation see Petersen (2000).

Zhivotovsky's F-ratio is a parametric method that is based on the standardized generalized variances (SGV). For each SGV, ratio of determinants, F-test statistic (F-ratio), and the significance of the F-test are calculated. A significant p-value indicates that there are higher levels of variability in the hypothesis sample than the reference sample. For this test, the natural log of the determinant ratio can be calculated as well, positive values are indicative of matrilocality whereas patrilocality is represented by negative values.

Wishart's bootstrap is a parametric bootstrap that works under the assumption that the samples under comparison are from the same population and utilizes a pooled variance-covariance matrix (Petersen, 2000). The pooled matrix is then randomly disturbed twice, with one perturbation based on the degrees of freedom for the hypothesis sample and the other on the degrees of freedom for they reference sample (Petersen, 2000). This is performed multiple

times, 999 for this analysis, and a p-value is calculated based off the bootstrap. Significance is at the 0.05 level; a significant p-value indicates higher levels of variation in the original test.

The nonparametric bootstrap method does not have any underlying assumptions and is best used for small and non-normally distributed samples (Petersen, 2000). This method is based on the raw data; the two samples compared are standardized, pooled, and then two samples are resampled with replacement from the pooled sample (Petersen, 2000). Covariance matrices are calculated based off the bootstrap samples, from this the determinant ratios are calculated. The bootstrap is performed 999 times in this analysis; the p-value is calculated from this bootstrap. Significantly different levels of variation in the hypothesis sample are represented by a p-value of 0.05 or less.

Chapter 4: Results

All configurations were successfully fitted with the generalized Procrustes analysis and the fitted data was subjected to both principal component and canonical variate analyses. The resulting principal components and canonical scores were used as the variables in the subsequent analyses.

Principal Component Analysis

Twenty-seven principal components were derived from the covariance matrix of the Procrustes coordinates from the 20 craniofacial landmarks for each configuration in the Sully, Larson, and Bad River samples. A PCA was only run on those three samples because they are the only samples whose homogeneity was tested; due to the nature of this analysis, the two samples being compared are pooled into a single sample for the PCA and for the intra-site analysis, Sully is the sole sample analyzed. All 27 principal components were used when comparing the variability between sites. However, only the first 13 principal components were utilized when comparing the variability between the sexes within each Sully burial area; these components represent approximately 90% of the total variation. A reduction in the number of principal components was necessary for this analysis due to the small samples sizes within each burial area. The eigenvalues, percent variance, and cumulative variance of these analyses can be found in Table 4.

Table 4. PCA Results

| | Bad River and Larson | | | Sully and Larson | | | Sully | | |
|-----|----------------------|--------|--------|------------------|--------|--------|------------|--------|--------|
| PC | Eigenvalue | % Var. | Cum.% | Eigenvalue | % Var. | Cum.% | Eigenvalue | % Var. | Cum.% |
| 1. | 0.000395 | 14.718 | 14.718 | 0.000486 | 16.517 | 16.517 | 0.000663 | 20.575 | 20.575 |
| 2. | 0.000311 | 11.579 | 26.297 | 0.000339 | 11.519 | 28.036 | 0.000411 | 12.771 | 33.345 |
| 3. | 0.000247 | 9.204 | 35.5 | 0.000292 | 9.936 | 37.972 | 0.000386 | 11.983 | 45.328 |
| 4. | 0.000224 | 8.364 | 43.864 | 0.000235 | 7.988 | 45.96 | 0.000288 | 8.954 | 54.282 |
| 5. | 0.000189 | 7.058 | 50.922 | 0.000211 | 7.16 | 53.12 | 0.000223 | 6.919 | 61.201 |
| 6. | 0.000158 | 5.891 | 56.814 | 0.000181 | 6.158 | 59.278 | 0.000211 | 6.543 | 67.744 |
| 7. | 0.000145 | 5.404 | 62.218 | 0.00015 | 5.105 | 64.383 | 0.000162 | 5.032 | 72.776 |
| 8. | 0.000136 | 5.076 | 67.294 | 0.00014 | 4.749 | 69.133 | 0.000124 | 3.849 | 76.625 |
| 9. | 0.000122 | 4.554 | 71.848 | 0.000122 | 4.145 | 73.278 | 0.000107 | 3.331 | 79.956 |
| 10. | 0.000111 | 4.128 | 75.976 | 0.000114 | 3.871 | 77.149 | 0.000105 | 3.246 | 83.201 |
| 11. | 0.0001 | 3.737 | 79.713 | 0.000101 | 3.437 | 80.586 | 8.41E-05 | 2.612 | 85.813 |
| 12. | 7.92E-05 | 2.95 | 82.664 | 7.99E-05 | 2.715 | 83.301 | 7.33E-05 | 2.276 | 88.089 |
| 13. | 7.11E-05 | 2.652 | 85.316 | 7.24E-05 | 2.459 | 85.76 | 6.54E-05 | 2.031 | 90.12 |
| 14. | 6.61E-05 | 2.464 | 87.78 | 6.79E-05 | 2.309 | 88.069 | 4.98E-05 | 1.544 | 91.664 |
| 15. | 5.28E-05 | 1.966 | 89.746 | 5.59E-05 | 1.902 | 89.971 | 4.79E-05 | 1.487 | 93.151 |
| 16. | 4.94E-05 | 1.841 | 91.587 | 4.89E-05 | 1.661 | 91.631 | 4.18E-05 | 1.298 | 94.449 |
| 17. | 4.25E-05 | 1.583 | 93.17 | 4.43E-05 | 1.504 | 93.136 | 3.74E-05 | 1.162 | 95.611 |
| 18. | 3.27E-05 | 1.219 | 94.39 | 4E-05 | 1.359 | 94.494 | 3.32E-05 | 1.029 | 96.64 |
| 19. | 2.78E-05 | 1.036 | 95.426 | 3.21E-05 | 1.092 | 95.587 | 2.47E-05 | 0.767 | 97.407 |
| 20. | 2.43E-05 | 0.907 | 96.333 | 2.65E-05 | 0.902 | 96.488 | 1.84E-05 | 0.57 | 97.977 |
| 21. | 2.3E-05 | 0.858 | 97.191 | 2.24E-05 | 0.761 | 97.25 | 1.67E-05 | 0.517 | 98.494 |
| 22. | 2.01E-05 | 0.75 | 97.941 | 2.12E-05 | 0.721 | 97.971 | 1.29E-05 | 0.399 | 98.893 |
| 23. | 1.64E-05 | 0.611 | 98.552 | 1.84E-05 | 0.624 | 98.595 | 1.18E-05 | 0.365 | 99.258 |
| 24. | 1.22E-05 | 0.455 | 99.008 | 1.49E-05 | 0.507 | 99.101 | 8.67E-06 | 0.269 | 99.527 |
| 25. | 1.18E-05 | 0.439 | 99.447 | 1.19E-05 | 0.405 | 99.506 | 6.97E-06 | 0.216 | 99.744 |
| 26. | 9.38E-06 | 0.35 | 99.797 | 9.53E-06 | 0.324 | 99.83 | 5.63E-06 | 0.175 | 99.918 |
| 27. | 5.46E-06 | 0.203 | 100 | 4.99E-06 | 0.17 | 100 | 2.63E-06 | 0.082 | 100 |

Tests of Homogeneity

To test the homogeneity at the Sully site, all 27 principal components from the combined Sully and Larson PCA were used. Zhivotovsky's F-ratio, Wishart's bootstrap, and the nonparametric bootstrap all found that the levels of variability within the Sully site are not significantly greater than those found in the Larson sample; p-values from these tests are 0.378, 0.602, and 0.667 respectively. The natural log of the determinant for this analysis was negative.

The amalgamated Bad River sample was tested to examine the level of variability within the sample using 27 principal components from a combined Bad River and Larson PCA. All three tests found non-significant levels of variation within the Bad River sample compared to that in the Larson sample. This analysis yielded a negative natural log of the determinant.

All 27 principal components from the PCA performed on all Sully individuals were used to test the level of homogeneity between the sexes. Both tests yielded non-significant results for all of the homogeneity tests. The test of matrilocality for the site yielded p-values of 0.733, 0.506, and 0.236 for Zhivotovsky's F-ratio, Wishart's bootstrap and the nonparametric bootstrap respectively. When the level of homogeneity of the females was compared to that of the males, the p-values yielded were: 0.267, 0.988, and 0.775 for each respective test. The matriloal test produced a positive value for the natural log of the determinant and the patriloal test produced a negative value. Results from the four previously described tests of homogeneity can be found in Table 5.

Table 5. Results for the Homogeneity Tests using Principal Components

| Comparison | N | Det. Ratio | Log(Det) | F-ratio | P-value |
|-------------------------|-----|------------|-----------|---------|---------|
| Sully/Larson | 203 | | | | |
| Zhivotovsky's F-ratio | | 0.04224 | -3.16435 | 1.014 | 0.378 |
| Wishart Bootstrap | | | | | 0.602 |
| Nonparametric Bootstrap | | | | | 0.667 |
| Bad River/Larson | 163 | | | | |
| Zhivotovsky's F-ratio | | 1.93e-06 | -13.15799 | 1.054 | 0.233 |
| Wishart Bootstrap | | | | | 0.224 |
| Nonparametric Bootstrap | | | | | 0.865 |
| Sully M/ Sully F | 69 | | | | |
| Zhivotovsky's F-ratio | | 18331.16 | 9.816358 | 0.934 | 0.733 |
| Wishart Bootstrap | | | | | 0.506 |
| Nonparametric Bootstrap | | | | | 0.236 |
| Sully F/ Sully M | 69 | | | | |
| Zhivotovsky's F-ratio | | 5.455e-05 | -9.816357 | 1.071 | 0.267 |
| Wishart Bootstrap | | | | | 0.988 |
| Nonparametric Bootstrap | | | | | 0.775 |

Comparisons of the levels of homogeneity between the males and females interred at each burial area in Sully yielded a result of 'NaN' (not a number). The number of principal components used was then reduced to less than the smallest subsample to account for any inherent statistical issues that arise from having more variables than cases in an analysis. However, reducing the variables from thirteen to seven did not change the results of the analysis. It was concluded that there may be an issue of singularity with the covariance matrices and that the principal component scores from within individual burial areas may not have the levels of variation present to perform this test.

To overcome the issue of possible singularity, a CVA was performed on the projected coordinates and the resulting canonical variate scores were used as variables for the homogeneity tests within the burial areas at Sully. Canonical scores represent the most

extreme differences between groups and should have enough variability between them to identify any differences between groups. Results from the CVA can be found in the next section.

Zhivotovsky's F-ratio, Wishart's bootstrap, and a nonparametric bootstrap were run using all five canonical scores as variables for each Sully burial area. For each burial area, Sully A, Sully D, and Sully E, the levels of variation in the male samples were not significantly different from that of the females. The test was then reversed to test the homogeneity of the females against that of the males for each burial area to test for a patrilocal pattern of post marital residence; again, differences in variability were not significant. The natural log of the determinant was positive for Sully A and negative for Sully D and Sully E when the variability in males was examined. When the variability of the females was examined, the natural log of the determinant was negative for Sully A and positive for both Sully D and Sully E. Full results of these analyses can be found in Table 6.

Table 6. Results for the Homogeneity Tests using Canonical Variates

| Test | N | Det. Ratio | Log(Det) | F-ratio | P-value |
|-------------------------|----|------------|------------|---------|---------|
| Sully A (M/F) | 21 | | | | |
| Zhivotovsky's F-ratio | | 9.508331 | 2.252168 | 1.179 | 0.357 |
| Wishart's Bootstrap | | | | | 0.679 |
| Nonparametric Bootstrap | | | | | 0.531 |
| Sully A (F/M) | 21 | | | | |
| Zhivotovsky's F-ratio | | 0.1051709 | -2.252169 | 0.848 | 0.643 |
| Wishart's Bootstrap | | | | | 0.359 |
| Nonparametric Bootstrap | | | | | 0.484 |
| Sully D (M/F) | 21 | | | | |
| Zhivotovsky's F-ratio | | 0.1102065 | -2.206307 | 0.676 | 0.859 |
| Wishart's Bootstrap | | | | | 0.157 |
| Nonparametric Bootstrap | | | | | 0.192 |
| Sully D (F/M) | 21 | | | | |
| Zhivotovsky's F-ratio | | 9.073873 | 2.205399 | 1.478 | 0.140 |
| Wishart's Bootstrap | | | | | 0.828 |
| Nonparametric Bootstrap | | | | | 0.798 |
| Sully E (M/F) | 27 | | | | |
| Zhivotovsky's F-ratio | | 0.5465789 | -0.6042596 | 0.728 | 0.858 |
| Wishart's Bootstrap | | | | | 0.152 |
| Nonparametric Bootstrap | | | | | 0.136 |
| Sully E (F/M) | 27 | | | | |
| Zhivotovsky's F-ratio | | 1.829562 | 0.6040793 | 1.375 | 0.142 |
| Wishart's Bootstrap | | | | | 0.849 |
| Nonparametric Bootstrap | | | | | 0.843 |

Canonical Variate Analysis

A CVA was performed to identify the variation that distinguishes the sexes by burial area for Sully. This test resulted in five canonical variates representing the significant spread between the groups. The canonical variate scores from this CVA were used as the variables for the tests of homogeneity between the sexes at each Sully burial area. Mean canonical scores for each component, eigenvalues, percent variance, and cumulative variance for these scores can be found in Table 7.

Table 7. Results from the CVA on Sully

| | CV1 | CV2 | CV3 | CV4 | CV5 |
|--------------|----------|----------|----------|----------|----------|
| SLA F | -1.07808 | 2.481324 | 0.172883 | 0.001162 | -0.78197 |
| SLA M | 0.328296 | 0.18083 | -1.37165 | 1.021954 | 0.434511 |
| SLD F | -0.86264 | 0.406491 | 0.837551 | -0.67009 | 1.165637 |
| SLD M | 0.278173 | -0.64082 | -1.46682 | -1.31577 | -0.33713 |
| SLE F | -2.00933 | -1.61698 | 0.576974 | 0.479221 | -0.42404 |
| SLE M | 1.782048 | -0.21696 | 0.998314 | 0.104218 | -0.20221 |
| | | | | | |
| Eigenvalues | 1.827024 | 1.328811 | 1.185482 | 0.610661 | 0.396178 |
| % Variance | 34.162 | 24.846 | 22.166 | 11.418 | 7.408 |
| Cumulative % | 34.162 | 59.008 | 81.174 | 92.592 | 100 |

It is evident from the mean canonical scores that the first canonical acts to distinguish morphological differences between the males and females at Sully. Plotting individuals by their first and second canonical scores and coloring them by sex clearly demonstrates this distinction; this plot can be found in Figure 4. Of particular interest in this plot are the patterns displayed by each sex; males are more closely clustered and the females are fairly spread out. Although the tests of homogeneity examining the levels of variation between the sexes were found to not be significant, it is evident that differences between the homogeneity of males and females

at Sully are present. This pattern expressed in the canonical plot supports the need for further investigation into whether or not admixture between Sully and nearby villages can be identified.

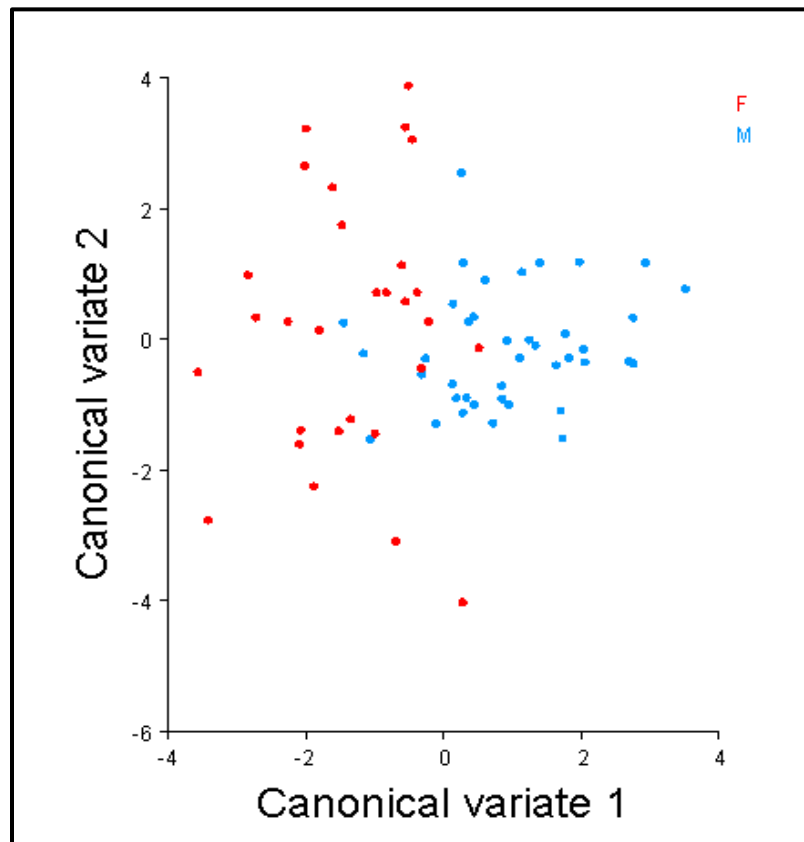


Figure 4. CV1 vs. CV2 Plot of the Sexes at Sully

Since the tests of homogeneity yielded non-significant results for both a pattern of matrilocality and patrilocality between the Sully burial areas, a CVA was performed between Sully and four additional Arikara components to examine possible levels of admixture between sites that may have interfered with the assumed pattern of post marital residence for the initial analysis. This test utilized both site and sex to classify individuals into groups. This CVA resulted in the production of 13 canonical variates, of which the first two account for nearly 55

percent of the total variation. The mean canonical scores, eigenvalues, percent variance, and cumulative percent for this analysis can be found in Table 8.

Table 8. Results from the CVA on Sully, Bad River, Rygh, and Mobridge Components

| Site and Sex | CV1 | CV2 | CV3 | CV4 | CV5 | CV6 | CV7 |
|--------------|----------|----------|----------|----------|----------|----------|----------|
| BR/F | -1.11654 | -0.16824 | 0.482496 | 0.60558 | -0.16186 | 1.136828 | 0.280759 |
| BR/M | -0.1617 | -1.11978 | 0.799062 | 0.679053 | 0.586058 | 0.277786 | -0.36194 |
| MBF1/3/F | 0.563464 | 1.041704 | 0.131629 | 0.033316 | -0.95704 | 0.320078 | -0.07859 |
| MBF1/3/M | 2.08584 | 0.388385 | 0.268303 | 0.20318 | 0.218622 | -0.25544 | 0.157477 |
| MBF2/F | -0.80198 | 1.093683 | 0.041227 | -0.54905 | 0.806042 | -0.02018 | 0.577476 |
| MBF2/M | 0.363268 | -0.71273 | 0.075003 | -0.81705 | 0.002315 | 0.136468 | -0.20144 |
| RG/F | -0.34771 | 2.171567 | 0.151098 | 0.232111 | -0.17394 | -0.13489 | -0.17877 |
| RG/M | 1.857022 | 0.318104 | -0.64454 | 0.393583 | -0.01355 | 0.024855 | -0.17784 |
| SLA/F | -1.30022 | 1.099817 | -0.59005 | 0.560532 | 0.869052 | -0.29261 | -0.84345 |
| SLA/M | 0.028943 | -0.84025 | 0.029013 | 0.57537 | -0.12437 | -0.56421 | 0.474498 |
| SLD/F | -1.82399 | 0.241386 | -0.37849 | -0.11297 | -0.27574 | -0.45593 | -0.84534 |
| SLD/M | -0.36808 | -0.98804 | 0.548021 | 0.480909 | -0.16908 | -1.17616 | 0.151217 |
| SLE/F | -1.75407 | -0.30261 | 0.502508 | -0.29024 | -0.94121 | -0.57744 | 0.43606 |
| SLE/M | -0.36778 | -0.87634 | -1.76765 | 0.275983 | -0.07078 | 0.194322 | 0.315207 |
| Eigenvalues | 1.214087 | 0.880707 | 0.37804 | 0.30116 | 0.251484 | 0.225416 | 0.153148 |
| % Variance | 31.709 | 23.002 | 9.873 | 7.865 | 6.568 | 5.887 | 4 |
| Cumulative % | 31.709 | 54.71 | 64.583 | 72.449 | 79.017 | 84.904 | 88.904 |

Table 8. Continued

| Site and Sex | CV8 | CV9 | CV10 | CV11 | CV12 | CV13 |
|--------------|----------|----------|----------|----------|----------|----------|
| BR/F | -0.03603 | 0.014219 | 0.195747 | -0.15096 | 0.027457 | -0.27817 |
| BR/M | 0.03561 | -0.06901 | -0.22349 | 0.265566 | -0.1401 | 0.237446 |
| MBF1/3/F | 0.035711 | 0.292221 | -0.37472 | -0.21854 | 0.013322 | 0.189016 |
| MBF1/3/M | -0.4335 | 0.198132 | -0.11863 | 0.241849 | 0.104901 | -0.17373 |
| MBF2/F | 0.054942 | 0.12588 | -0.09869 | -0.08698 | -0.19436 | 0.061426 |
| MBF2/M | 0.090825 | -0.05991 | 0.082899 | -0.03626 | 0.108403 | -0.01575 |
| RG/F | 0.656585 | -0.40721 | 0.285951 | 0.506921 | 0.25417 | -0.00518 |
| RG/M | 0.030228 | -0.48918 | 0.360049 | -0.28419 | -0.51157 | 0.007372 |
| SLA/F | -0.58951 | -0.26206 | -0.08907 | -0.58765 | 0.51633 | 0.029701 |
| SLA/M | 0.073596 | 0.470093 | 0.724763 | -0.14666 | 0.212924 | 0.21714 |
| SLD/F | -0.13945 | 0.682494 | 0.179904 | 0.23707 | -0.3979 | -0.1716 |
| SLD/M | 0.699486 | -0.14304 | -0.51696 | -0.36049 | -0.03239 | -0.25651 |
| SLE/F | -0.8193 | -0.69099 | 0.014718 | 0.17667 | -0.09856 | 0.076055 |
| SLE/M | 0.072553 | -0.03502 | -0.29031 | 0.246858 | 0.09215 | 0.009882 |
| Eigenvalues | 0.107521 | 0.096449 | 0.084464 | 0.063917 | 0.048954 | 0.02355 |
| % Variance | 2.808 | 2.519 | 2.206 | 1.669 | 1.279 | 0.615 |
| Cumulative % | 91.712 | 94.231 | 96.437 | 98.106 | 99.385 | 100 |

Over half of the total variation between the site and sex components for this analysis is accounted for in the first two canonical variates; the first canonical accounting for approximately 32 percent of the total variance and the second canonical containing about 23 percent. Each canonical identifies particular variations in morphology that operate to separate the predefined groups in the analysis; individuals that fall on opposite sides of the canonical, positive or negative scores, display opposing morphological expression for the areas identified by the canonical as being important separating factors.

Plotting each village component by its mean canonical score along the first and second canonicals makes the relationships between the sexes from each site fairly easy to recognize. The level of congruence between the males from the Sully burial areas with those from Mobridge F2 and Bad River is the most apparent; the centroids for these components tightly cluster away from the males from Mobridge F1/3 and Rygh. This pattern attests to the close relationship between these groups. The level of variability between the females of each village component is also apparent in the plot of the mean canonical scores. Unlike the male components, the females are spread apart, forming a loose cluster along the canonicals; thus reflecting the varying degrees of relationships that each Sully component experiences with the other Arikara village components. A plot of mean canonical scores for each Arikara village component with morphological depiction of the canonical variate loads along the axes can be found in Figure 5.

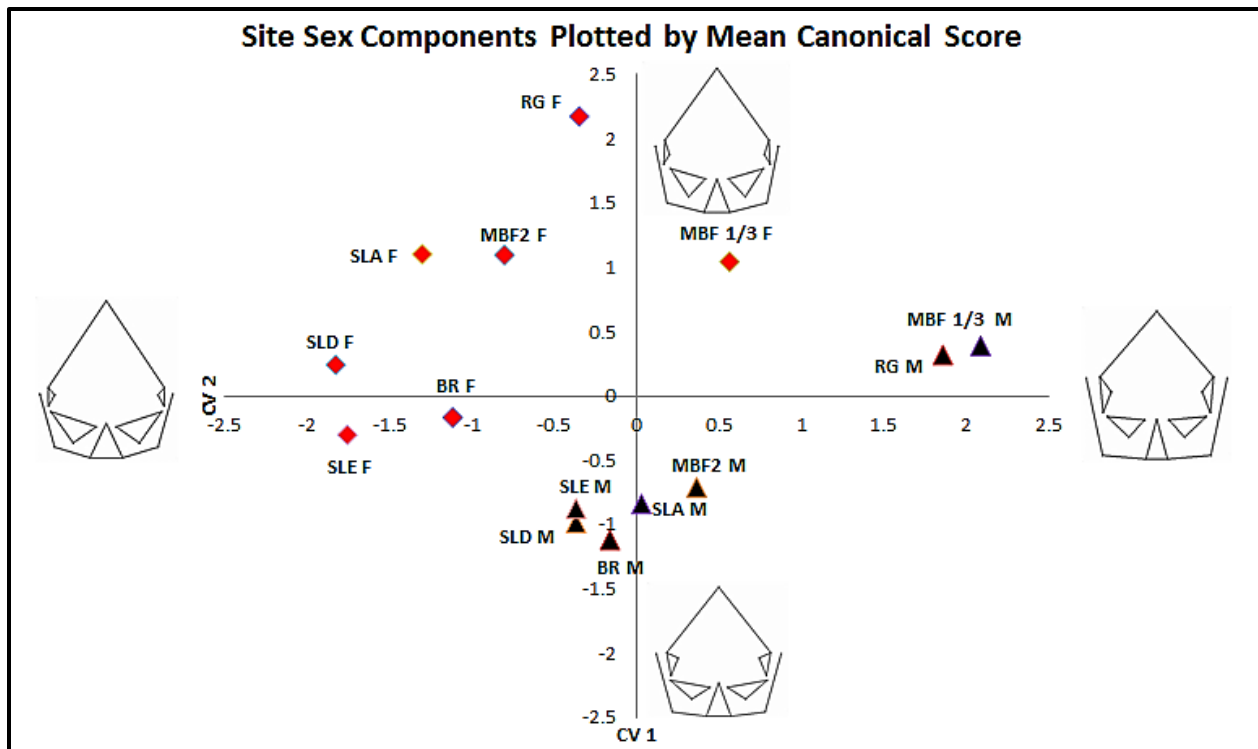


Figure 5. Plot of mean canonical scores for each Arikara village component

Due to the large proportion of variance accounted for in the first two canonicals, a scatter plot of individuals by their canonical scores was produced to help visualize the relationships between the different components. The scatter plot of all individuals plotted by their first two canonical scores can be found in Figure 6.

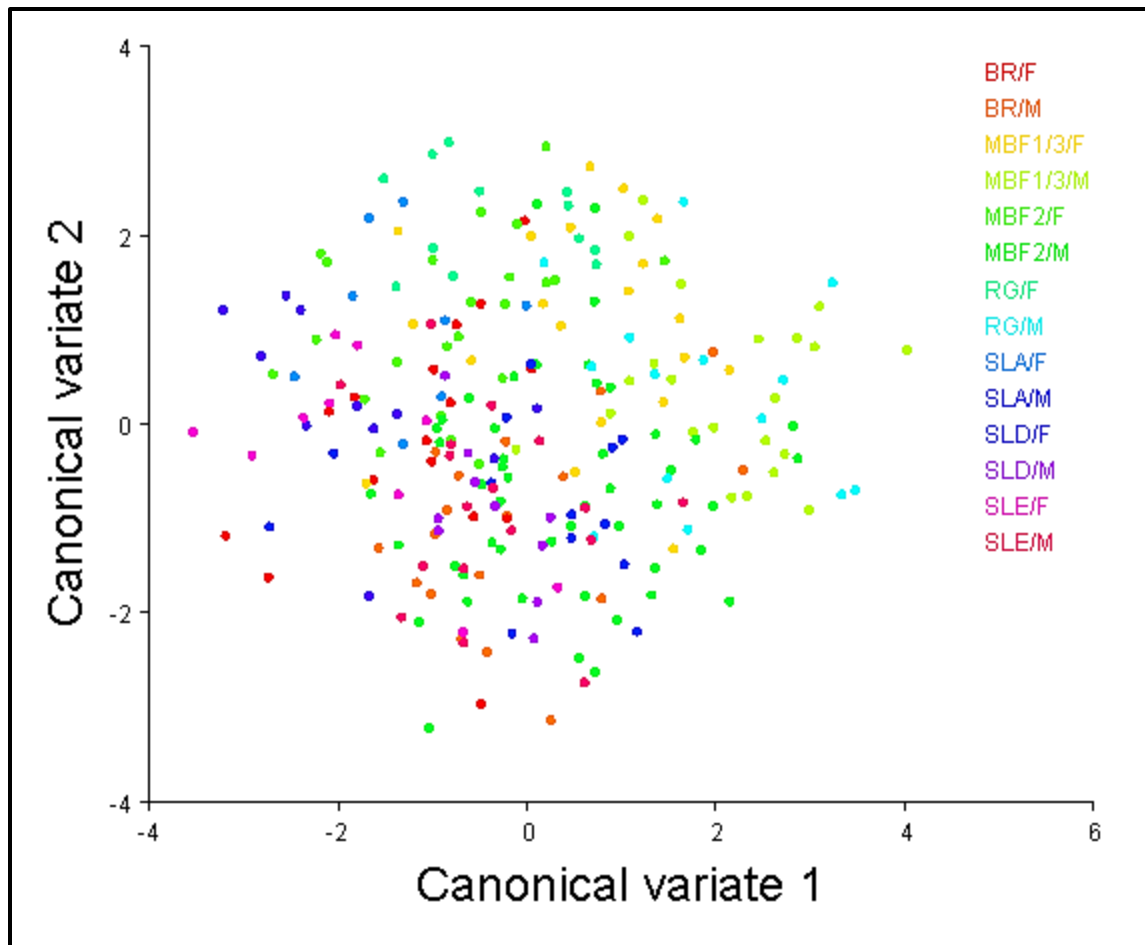


Figure 6. CV1 vs. CV2 plot of individuals from Sully, Rygh, Bad River, and Mobridge components

The scatter plot illustrated in Figure 6 shows a clear overlap of many individuals from multiple components included in the analysis. Although individual relationships are difficult to discern from this plot, a separation of both the male and female component of Mobridge F1/3 and the male Rygh component from the majority of the group is evident. Isolation of the sexes within the scatter plot makes the relationships between the components more apparent. Isolation of the components by sex can be found in Figures 7 and 8; these figures show the relationships between the males and females of each village component respectively. A break-

down of the relationship between individuals from each Sully burial component and each additional Arikara village component by sex can be found in Appendix D.

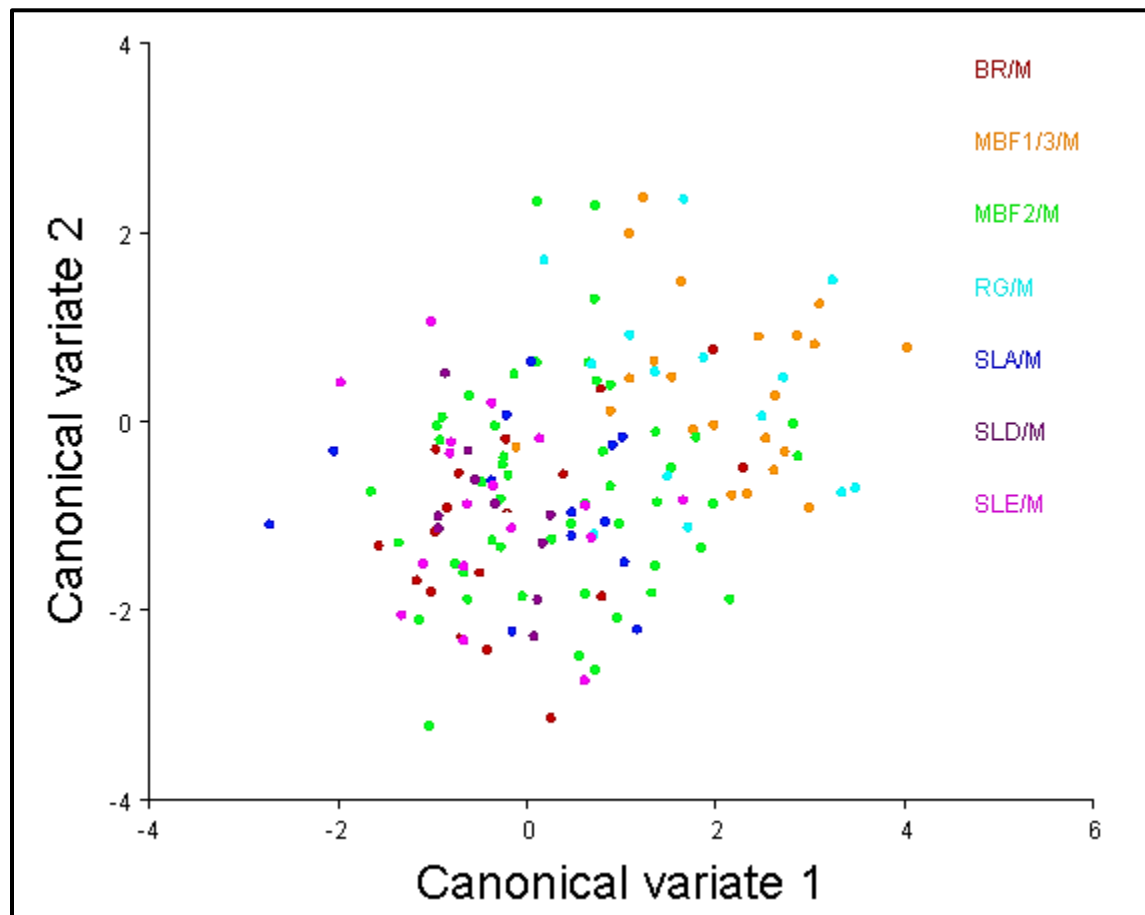


Figure 7. CV1 vs. CV2 plot of males from Sully, Rygh, Mobridge F1/3, Bad River, and Mobridge F2

From the scatter plots of individuals, the relationships between individuals from each component can be seen. As illustrated in Figure 7, and more clearly in Figures A-D in Appendix D, the males from all three Sully components experience high levels to almost complete overlap with the males from both Bad River and Mobridge F2. Whereas there is very little to no overlap experienced by the Sully males from any burial area with the males from Mobridge F1/3 and Rygh.

As seen in Figure 8, as well as Figures E-H in Appendix D, the females from each Sully burial area have less clear-cut relationships with the outside village components. Individuals from all three Sully burial areas display very little to no overlap with individuals from Mobridge F1/3; there is also no overlap between the females from Sully D and Sully E and those from Rygh. The females from Sully A experience considerable overlap with females from Rygh, Bad River, and Mobridge F2. There is a high level of overlap displayed between the females of Sully D and Sully E and the females from Bad River, but only moderate overlap with Mobridge F2.

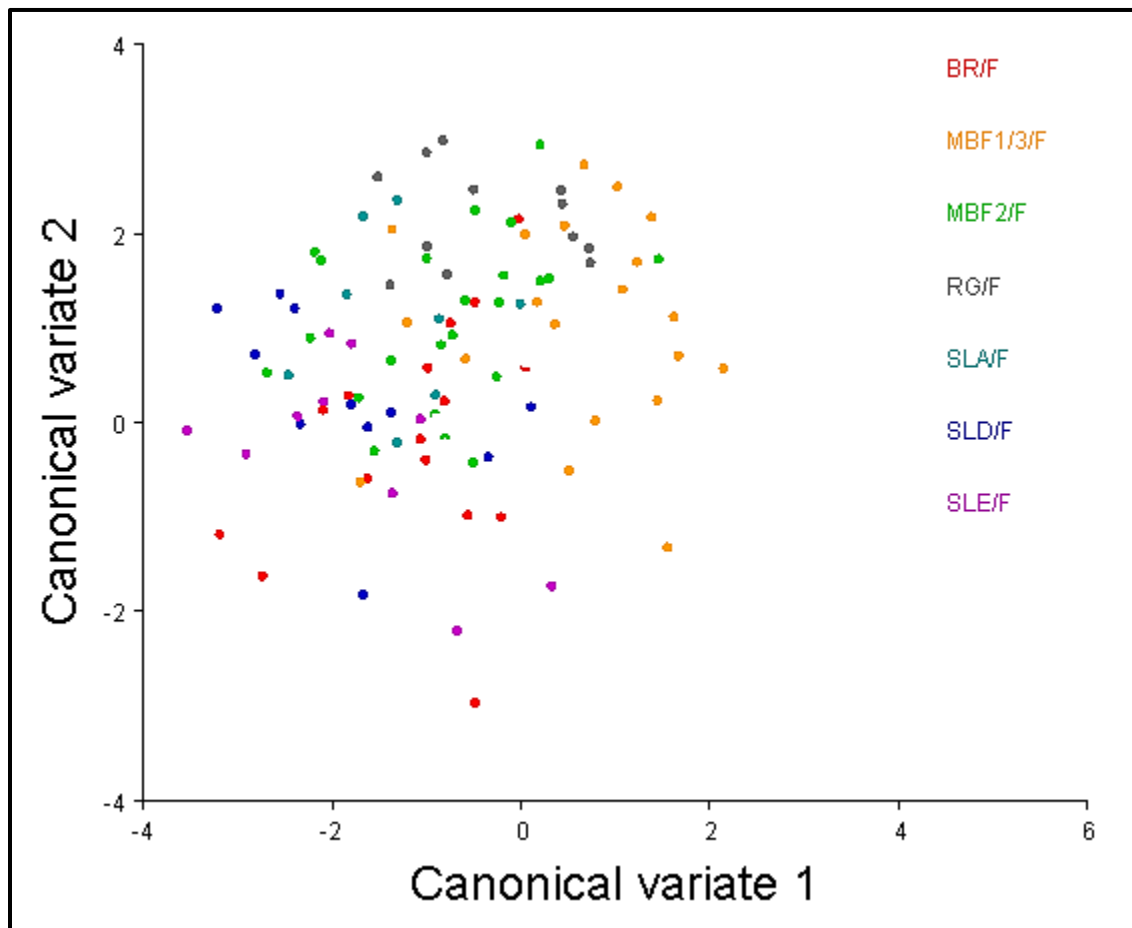


Figure 8. CV1 vs. CV2 plot of females from Sully, Rygh, Mobridge F1/3, Bad River, and Mobridge F2

The first canonical from this analysis identifies bregma, the zygomatic roots, nasal width, zygomatic shape, and orbit shape to be the areas where the greatest levels of variation between groups exists. Individuals who fall on the positive side of the first canonical have a low cranial height, a narrow nasal aperture, little slant to the orbits, a large face, and elongated, projecting zygomatics. Whereas individuals who score negatively along the first canonical have a high cranial height, a wide nasal aperture, small face, low and slanted orbits, and receding zygomatics. Visualization of the morphologies associated with the first canonical can be found in Figure 9. The mean shape along the canonical is represented by the gray wireframe, the target shape is blue, and the landmark numbers are purple; the scale factor has been set to 10 to emphasize the morphological differences between positive and negative loads.

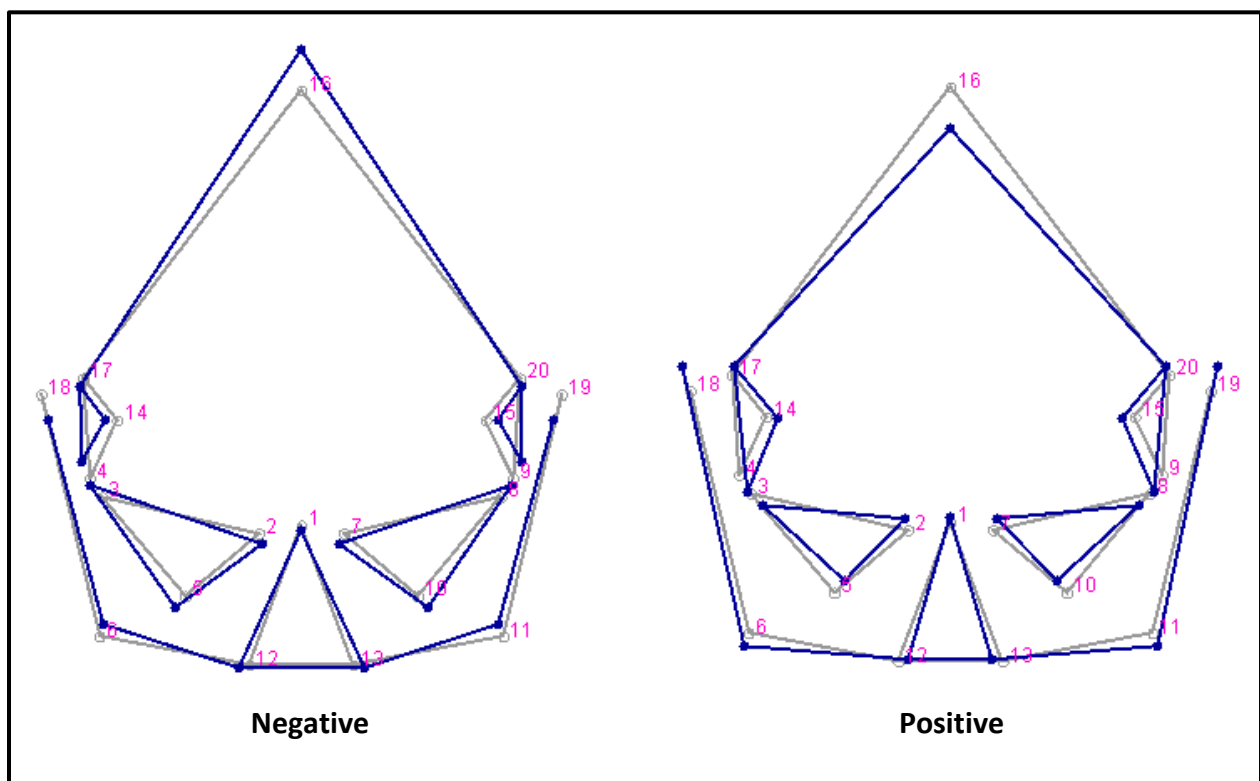


Figure 9. Wireframe graphs of morphological differences displayed by CV1

The second canonical variate from this analysis identifies the nasal aperture, bregma, the orbits, the zygomatics, and vault width as the areas on the cranium used to distinguish between groups. Individuals who score positively along the second canonical have a tall cranial vault, narrow forehead, short nasal aperture, narrow, slanted orbits, projecting zygomatics, and a small face. Individuals with a negative score along the second canonical have a short cranial vault, wide forehead, slanted orbits, a tall nasal aperture, receding zygomatics, and a large face. Figure 10 displays visualizations of the differing morphological patterns along the second canonical. As in the graphics for the first canonical, the mean shape is gray, the target shape is blue, and the landmark numbers are purple. The graphs have been set to a scale factor of 10 to emphasize the morphological differences between the loadings. It should be noted that the differences in morphology displayed along the second canonical are less severe than those identified in the first canonical.

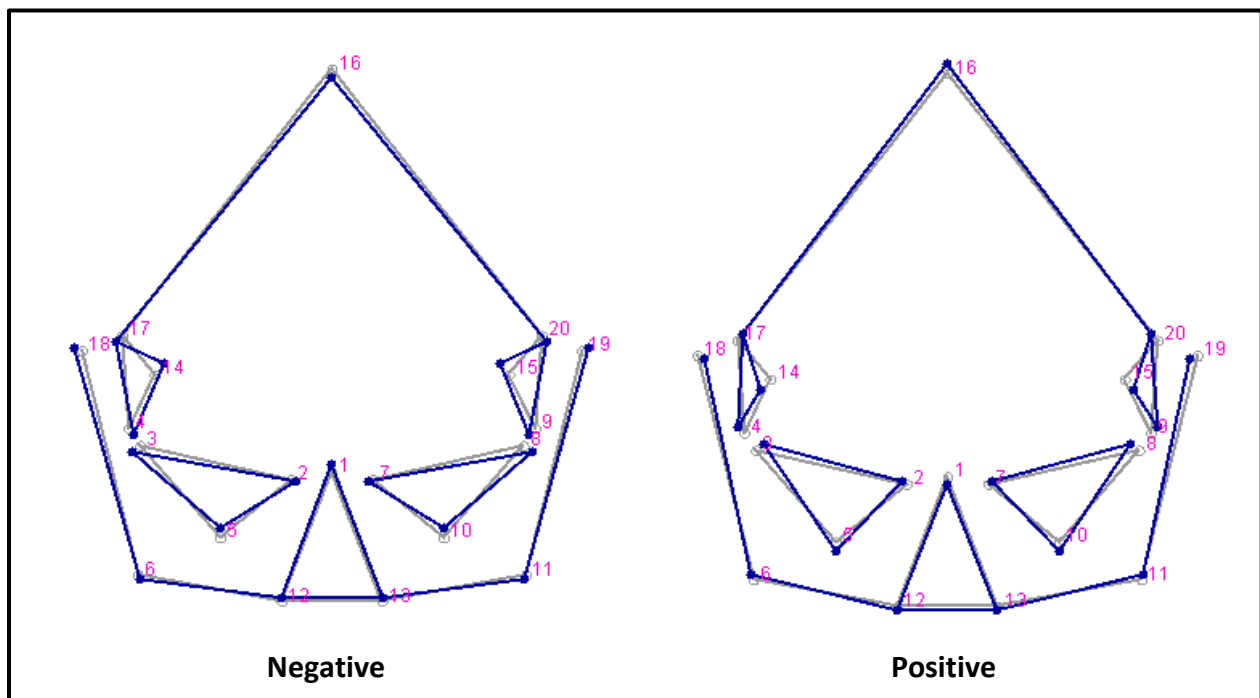


Figure 10. Wireframe graphs of morphological differences displayed by CV2

Mahalanobis Distances

Mahalanobis distances between each Arikara sample were calculated for the CVA, shown in Table 9. Significance for these values was calculated using a permutation test of 10,000 repetitions. The permutation test identified multiple components that were not significant from each other; the centroids for these groups are similar enough that they cannot be accurately distinguished from one another.

All of the Sully components, except for Sully E males, have at least one Mahalanobis distance value with a non-Sully village component that is not significant. The males from Sully A and Sully D and the females from Sully D and Sully E exhibit non-significance with the male and female components of Bad River, for each respective sex. However, the females from Sully A have non-significant Mahalanobis distances with the females from Mobridge F2 and Rygh.

The Sully components also display non-significance with each other; females from Sully A, Sully D, and Sully E are all reported as not being significantly different from each other. All the males, except those from Sully D and Sully E, also have non-significant Mahalanobis distances. The Mahalanobis distance matrix and p-value for each comparison can be found in Table 9; p-values indicating non-significance are highlighted in yellow.

Overall the results from this study do not support the research hypothesis of significant morphological variation between the males and females at Sully, and as such the null hypothesis is accepted. Tests of homogeneity were able to show that the individuals at Sully can be used as a single, cohesive sample and that intra-site patterns of post marital residency cannot be revealed. Canonical variate analysis of Sully demonstrates that although phenotypic variation between the sexes is not significant, that differential patterns of heterogeneity exist

within the sample. Comparison with the samples from Anton Rygh, Mobridge, and the amalgamated Bad River samples show high levels of overlap with the Sully sample. These patterns expressed in the canonical plots may reveal relationships between these villages that would interfere with the expected patterns of post marital residency at Sully.

Table 9. Mahalanobis distance matrix and significance level between Arikara village components

Mahalanobis distances among groups:

| | BR/F | BR/M | MBF1/3/F | MBF1/3/M | MBF2/F | MBF2/M | RG/F | RG/M | SLA/F | SLA/M | SLD/F | SLD/M | SLE/F |
|----------|--------|--------|----------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| BR/M | 2.0708 | | | | | | | | | | | | |
| MBF1/3/F | 2.607 | 2.9895 | | | | | | | | | | | |
| MBF1/3/M | 3.6514 | 3.0092 | 2.282 | | | | | | | | | | |
| MBF2/F | 2.4205 | 2.9366 | 2.4597 | 3.2447 | | | | | | | | | |
| MBF2/M | 2.4616 | 1.9759 | 2.2879 | 2.4641 | 2.4779 | | | | | | | | |
| RG/F | 3.0607 | 3.647 | 2.2159 | 3.3522 | 2.211 | 3.2916 | | | | | | | |
| RG/M | 3.5408 | 3.1266 | 2.3194 | 1.6667 | 3.3176 | 2.4498 | 3.2594 | | | | | | |
| SLA/F | 2.8552 | 3.233 | 3.1249 | 3.924 | 2.3017 | 3.2781 | 2.6926 | 3.704 | | | | | |
| SLA/M | 2.3837 | 2.0292 | 2.6834 | 2.7582 | 2.8032 | 1.9502 | 3.4263 | 2.7565 | 3.2667 | | | | |
| SLD/F | 2.5582 | 3.0228 | 3.0453 | 4.2166 | 2.4795 | 2.8649 | 3.0365 | 4.0471 | 2.3602 | 2.8423 | | | |
| SLD/M | 2.7822 | 2.0711 | 3.024 | 3.3192 | 3.0287 | 2.3056 | 3.607 | 3.3621 | 3.4162 | 1.8917 | 2.9554 | | |
| SLE/F | 2.488 | 3.0235 | 3.2437 | 4.2559 | 2.836 | 2.8715 | 3.4972 | 4.2518 | 3.209 | 2.8252 | 2.3955 | 2.7049 | |
| SLE/M | 2.7618 | 2.804 | 3.0885 | 3.5292 | 3.0274 | 2.3766 | 3.7739 | 3.0338 | 3.18 | 2.3617 | 2.8839 | 2.8711 | 3.2338 |

P-values from permutation tests (10000 permutation rounds) for Mahalanobis distances among groups:

| | BR/F | BR/M | MBF1/3/F | MBF1/3/M | MBF2/F | MBF2/M | RG/F | RG/M | SLA/F | SLA/M | SLD/F | SLD/M | SLE/F |
|----------|--------|--------|----------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| BR/M | 0.118 | | | | | | | | | | | | |
| MBF1/3/F | 0.0001 | <.0001 | | | | | | | | | | | |
| MBF1/3/M | <.0001 | <.0001 | 0.0007 | | | | | | | | | | |
| MBF2/F | <.0001 | <.0001 | <.0001 | <.0001 | | | | | | | | | |
| MBF2/M | <.0001 | 0.0017 | <.0001 | <.0001 | <.0001 | | | | | | | | |
| RG/F | <.0001 | <.0001 | 0.0746 | <.0001 | 0.0415 | <.0001 | | | | | | | |
| RG/M | <.0001 | <.0001 | 0.01 | <.0001 | <.0001 | <.0001 | <.0001 | | | | | | |
| SLA/F | 0.0384 | 0.0014 | 0.0004 | 0.5498 | <.0001 | <.0001 | <.0001 | <.0001 | | | | | |
| SLA/M | 0.0309 | 0.2686 | 0.0002 | <.0001 | 0.226 | <.0001 | 0.217 | <.0001 | 0.002 | | | | |
| SLD/F | 0.0504 | 0.0008 | <.0001 | <.0001 | 0.0077 | <.0001 | 0.0015 | 0.0003 | 0.792 | 0.0059 | | | |
| SLD/M | 0.0024 | 0.4254 | 0.0002 | <.0001 | <.0001 | 0.0122 | <.0001 | <.0001 | 0.001 | 0.687 | 0.0079 | | |
| SLE/F | 0.0704 | 0.0013 | <.0001 | <.0001 | 0.0004 | <.0001 | 0.0001 | <.0001 | 0.0533 | 0.0128 | 0.4602 | 0.0556 | |
| SLE/M | 0.0001 | 0.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | 0.0166 | 0.0654 | 0.0058 | 0.0042 | 0.0007 |

Chapter 5: Discussion

The purpose of this study is to identify factors contributing to the morphological variability present between the three burial areas at the Sully site; the primary factor analyzed for this examination is post marital residency pattern. Such a study is warranted based on the lack of agreement by previous research seeking to explain the presence of multiple, geographically distinct burial areas at Sully through cranial morphology. It has generally been accepted that the differences in morphology between the Sully burial areas is due to temporal separation of the burial sites. However, studies asserting that there is a temporal trend to the sites lack hard craniometric or archaeological evidence to support this claim.

Key's (1983) chronology of the Sully burials was based on the individuals from the separate burial areas appearing morphologically similar to different Arikara villages. The scores from the canonical were then paired with results from a dendrochronology performed by Weakley (1971) on the Sully site to determine temporal order to the burial areas. However, the dendrochronological analysis from Sully was based on samples collected from the village and within Sully A (Weakly, 1971); there were no samples taken from any of the other burial areas. Since the dendrochronology cannot be applied as a dating technique for individual burial areas, the only evidence for temporality is craniometric similarity between samples.

Owsley and Jantz (1978) also relied on a limited series of craniometric variables to determine a temporal order to the burial areas at Sully. In this analysis the canonical scores were used to infer temporal order, but the ordering of the sites differed between males and females; this holds true for both the Sully components as well as two of the reference sites

(Anton Rygh and Murphy). The change in position of Anton Rygh and Murphy between the CVAs performed on the sexes is especially problematic; these are two sites that are known to be temporally separated and if the CVA is truly showing temporal ordering, then the position of these sites along the canonical should not change. Statistical correlation with time was not examined in this study and thus, temporality at Sully was based on contradictory results from the canonical analysis.

The study by McKeown and Jantz (2005) did test for a correlation between time and morphology. This study identifies Sully E as comparing favorably with earlier Arikara sites and contradicted the long-held assumption of temporality to explain the observed similarities with Sully E being later than A and D. Again, the assertion of a temporal order lacks hard craniometric or archaeological evidence as support. This study also found higher levels of bilateral asymmetry in Sully E over both Sully A and Sully D; it was suggested that the asymmetry in Sully E may be a contributing factor to its divergence from the other burial areas.

Agosto and McKeown (2012) also identified significant differences in craniofacial morphology between the burial areas at Sully, but were unable to identify a temporal trend to the sites. Results from linear regression analyses examining the relationship between morphological variation and time yielded non-significant correlations for the two variables; this paired with the distribution of Euro-American trade items between the sites suggests a temporal order is not responsible for the observed morphological differences between burial areas. This study found evidence against a temporal trend between the Sully burial areas, but did not identify factors influencing the observed morphological differences.

Euro-American trade items have been found to be lacking in the samples used for the studies assessing temporality; indicating that a temporal trend should not be present in the available cranial data. Distribution of grave goods within the Sully cemeteries also does not support temporal ordering to the burial areas; comparable levels of Euro-American trade items are present. Additionally, it was found that at most, 11 percent of the individuals interred within a burial area were associated with trade goods and a majority of those individuals were sub-adults (Agosto and McKeown, 2012). The low ratio of Euro-American trade goods within the population and the disparities between adults and sub-adults interred with Euro-American trade items may suggest abandonment of the Sully site shortly after the arrival of these items around 1650 AD. This line of evidence does not support the idea of Sully occupation spanning multiple temporal components, as suggested in past research.

Although there is some archaeological evidence in the form of pottery style that does support multiple occupation periods at Sully, evidence from the village supports continual occupation of the site (Johnson, 2007) as does the distribution of grave goods in the burial areas. Each burial area contains approximately the same percentage of Euro-American trade items, which would suggest continual and contemporaneous use of the cemeteries through time. The utility of using trade items to infer relative dating has come into question in the burial context within villages with middlemen trade involvement. These concerns were demonstrated to be unfounded when dealing with the Arikara based on their mortuary customs (Orser and Owsley, 1982).

The inclusion of grave goods is common in Arikara mortuary practices. It was customary for the Arikara to include only new items in the burial and the best that could be afforded by

the family (Orser and Owsley, 1982). This brings into question whether the grave good distribution could be used as a relative date or if it is a reflection of social status. Ranking of burials according to social rank based on affiliation with certain grave goods is a common practice in mortuary archaeology, but is not applicable to Arikara burials. The role the Arikara played in the inter-tribal trade network subterfuges the traditional interpretations of grave good distribution; due to the wealth trading practices brought to the tribe, social boundaries were blurred and individuals were able to quickly elevate their social rank. Since social ranks within Arikara society were not strictly upheld, using grave good distribution to infer social status would produce inaccurate interpretations and their utility is better served to infer relative dates.

Evidence from the above studies indicates that both cranial and archeological data suggest that the differences in craniofacial morphology observed between the Sully burials does not correspondent to temporal separation of the burial areas. The current study demonstrates that differential levels of admixture with nearby, contemporaneous Arikara villages may be responsible for the observed differences in craniofacial morphology between the burial areas. This study was also able to find evidence for a possible patrilocal pattern of post marital residency on the site level, further supporting that village endogamy was not strictly adhered. The variability present within the Sully site is no greater than that of a single component Arikara site and can be considered a single sample in future analyses. These factors affecting morphology have yet to be identified or discussed in the literature and may provide greater insight into the life ways of the early Arikara population.

Homogeneity at Sully and Bad River

The levels of homogeneity were tested on the site level for both Sully and the Bad River amalgamation; Larson was used as the reference sample for each test. For each test the levels of variation between the hypothesis and reference sample was not significant. In terms of the agglomerated Bad River sites, it indicates that the level of variation between the sampled individuals is low enough, that for the purposes of this study, the samples from the four right bank sites could be pooled to create a sample of adequate size. This finding is congruent with the findings of Key and Jantz (1990) during their evaluation of the homogeneity between Bad River 2 sites.

The presence of distinct burial areas at Sully has resulted in the areas being considered separate samples. Non-significance of Zhivotovsky's F-ratio, Wishart's bootstrap, and the nonparametric bootstrap run with all individuals from Sully as the hypothesis sample and Larson as the reference sample, suggest that the level of variation present between the three burial areas at Sully is no greater than that of a single component Arikara site. Results from this test indicate that Sully does not need to be separated into subsamples based on burial area and, depending on the nature of the study, can be used as a single sample.

Additionally, the natural log of the determinant derived from Zhivotovsky's F-ratio on Sully and Larson was negative, suggesting a patrilocal pattern of post marital residence for the Sully site as a whole. This is contradictory to the ethnohistoric accounts of post marital residence in Arikara society. Implications and further support for this finding will be discussed shortly.

The primary analyses for this study involved testing for a known pattern of post marital residence between the Sully burial areas A, D, and E through investigating relative levels of variation between the sexes. These analyses failed to find the expected post marital residence pattern of matrilocality; the males in each burial area did not exhibit more variation than the females. Upon failure of the test for matrilocality, the test was inversed to test for patrilocality between the burial areas. Again, the level of variation between the sexes was not significantly different.

Since Zhivotovsky's F-ratio, Wishart's bootstrap, and the nonparametric bootstrap were unable to identify significantly different levels of variation in one sex over the other for any of the Sully burial areas, the null hypothesis guiding this research cannot be rejected. Acceptance of the null hypothesis indicates that there is either an issue with the presumed pattern of post marital residence or one of the underlying assumptions about the samples. Sex estimation and group affinity have been evaluated by the Smithsonian Institution (Billeck et al., 2005) and although there is always an inherent level of error associated with such analyses, based on the source of this information, it is presumed that the level of error in these factors would be minimal and would not affect the outcome of the post marital residence analyses. Because one of the overall goals of this research is to identify whether or not there are factors other than time that can explain the morphological variability at Sully, biological influences that would affect the presumed pattern of post marital residence were examined. Specifically, evidence of gene flow or admixture with nearby villages was considered and tested via CVA.

Evidence of Inter-Village Admixture

Canonical variate analyses were performed to examine any factors that may be influencing the morphological variability at Sully that may interfere with the expected post marital residence pattern of matrilocality. The CVA performed on Sully A, Sully D, and Sully E was originally run in order to utilize the canonical variates as variables for the homogeneity tests involving just the Sully burials. However, the scatter plot of individuals colored by sex revealed an unexpected pattern: tighter clustering of males with the females being spread out.

The pattern present in the scatter plot is what would be expected if females were being brought into the village from an outside source; recall from Konigsberg (1987) that the more mobile sex is more heterogeneous or variable than the stationary sex. This finding corresponds with the patrilocal post marital residence pattern identified in the Sully/Larson homogeneity test; both sources of evidence suggest that individuals, possibly women, were being brought into the village from an outside source. This finding is contradictory to the expected patterns described in the ethnohistoric accounts recorded nearly 100 years after Sully was occupied and would interfere with the post marital residence tests on the burial areas. However, this interpretation should be taken with a level of caution because neither sex was found to be more variable than the other in the homogeneity tests. If admixture with outside villages was taking place at Sully, it is possible that either the rates of admixture were not high enough to change the village dynamic or that admixture was occurring with morphologically similar groups.

To test for further evidence of inter-village mate exchange, a canonical variate analysis was performed to determine whether or not there were any significant levels of admixture

between Sully and nearby, contemporaneous Arikara villages. The results of the CVA show that all components from Sully are significantly different from both the males and females from Mobridge F1/3 and the males from Rygh. Additionally, plotting the individuals by CV1 and CV2 shows very little to no overlap between individuals from these components. This indicates that there was not admixture occurring between any of the Sully components and these outside site components. It would be possible that any similarities between these site components are most likely due to population affinities between all of the Arikara.

Evidence for a strong relationship between the Sully components and those from Mobridge F2, Bad River, and the female Rygh component is present within the results of the CVA. Not only are the Mahalanobis distances between these sites and the Sully burial components not significant, but there are very high levels of overlap between individuals in these components. The manner in which individuals relate to each other in the first and second canonical is such that these groups cannot be differentiated from one another. The level of affinity present between the individuals at Sully and those from Mobridge F2, Bad River, and the females of Rygh goes beyond what would be expected if the similarities were simply the result of population affinity; instead, these results suggest that there was either some degree of admixture between these groups or that one of these groups may be ancestral to the others.

All of the results from the CVA between male and female components from the Sully burials, Rygh, Mobridge F1/3, Mobridge F2, and Bad River uphold the assertion that the expected pattern of post marital residency and village endogamy at Sully does not hold. These results appear to suggest that there may have been some level of inter-site marital migration

and admixture taking place that would interfere with any test of intra-site post marital residency at Sully.

Interpretations

The morphological patterns revealed in the canonical variate analysis can be interpreted as being the result of either an ancestral relationship between sites or as support for the presence of inter-village admixture. Johnson (1998) suggests an ancestral relationship between Sully and several Le Beau and Bad River phase sites along the Missouri River. It is posited that at the end of the Extended Coalescent, Sully had expanded beyond its carrying capacity and broke off into several semi-autonomous village groups. These village groups are believed to have contributed to emerging Bad River and Le Beau phases in the Bad-Cheyenne and Grand-Moreau regions.

The CVA comparing Arikara village components shows a strong degree of similarity between Sully, Mobridge F2, and Bad River groups; Mobridge F2 is a Le Beau phase village in the Grand-Moreau region and the amalgamated sample comprised of Black Widow Ridge, Indian Creek, Leavitt, and Cheyenne River are located in the Bad-Cheyenne region and are considered to belong to the Bad River phase. It is possible that Sully is ancestral to both the late component at Mobridge and the agglomerate Bad River villages, and that the relationship presented in the CVA may be largely attributed to the ancestral nature of these groups and not inter-village admixture.

Even if the observed similarities between groups are the result of Sully being ancestral to the late Mobridge component and Bad River villages, admixture between these groups cannot be discounted. The formation of semi-autonomous village groups from the larger Sully

village most likely did not cut all social connections between the groups, especially in an area that does not impede travel over large distances, such as the Plains. Relationships between clans and kin groups were probably kept intact through a system of marital migration between the groups. Admixture between villages would also help retain morphological similarity through time. So it is quite possible that even though Mobridge F2 and the amalgamated Bad River villages are composed of individuals originating from Sully, that inter-village admixture was also occurring.

Evidence for inter-village admixture and marital migration is most apparent in the relationship between the females from Sully A and the females from Rygh. Anton Rygh is a La Roche phase Arikara village and was occupied during the early part of the Extended Coalescent. Sully A females are the only component from Sully to have any overlap in the CVA or non-significant Mahalanobis distance with an early La Roche village component. It could be argued that after the dissolution of Rygh, individuals may have migrated south and relocated to Sully. This is a possible scenario, but it lacks craniometric and archaeological evidence and it is unlikely that only females made the journey south after Rygh's abandonment. Since the affinities are only present between the females at Sully A and the females from Rygh, it is most likely that the individuals who were interring their dead in the Sully A burial area, possibly a clan group, were taking part in a system of inter-village admixture and marital migration.

The morphological similarities and group affinities evident in the canonical variate analysis attest to the presence of complex relationships between Sully and other contemporaneous Arikara villages. The observed levels of similarities in this analysis cannot be written off as simply population affinity; if this were the case, then overlap amongst all

individuals and non-significant Mahalanobis distances present in all the Arikara components would be expected. However, there are some components in this analysis that do not display these characteristics, and therefore, similarities must be attributed to factors other than population affinity.

Results from this analysis suggest that differential levels of admixture between the individuals interred in Sully A, Sully D, and Sully E may be responsible for the differences in morphology observed between the burial areas. Although individuals from each village examined have been found to be both culturally and morphologically affiliated with the Arikara, there are subtle, yet significant differences in morphology that can be used to differentiate individuals based on village.

McKeown (2000) and McKeown and Jantz (2005) identified significant correlation between craniofacial morphology and geography within the Arikara population and it was concluded that homogeneity of the Arikara population was maintained by gene flow and migration of individuals through time. Additionally, villages within close geographic proximity to each other, such as Anton Rygh, Mobridge, and Larson bear a high degree of similarity between them; this may suggest a level of inter-village admixture between these sites. Although a pattern of clan exogamy and village endogamy has been reported for the Arikara (Holder, 1970; Rogers, 1990; Parks, 2001), evidence for marital migration between villages exists. Schneider and Blakeslee (1990) utilized enamel composition to demonstrate greater levels of heterogeneity among males from several Arikara villages and concluded that inter-village migration was responsible for this pattern.

Evidence of marital migration is present for several early Arikara villages, including those described in this study. Inter-village marital migration is contradictory to the ethnohistoric accounts, which claim villages were endogamous. However, observations in the ethnohistoric accounts were made in the mid to late 1800s by European traders and explorers after the Arikara population had been decimated by disease and their society changed by Euro-American contact. The Arikara suffered great population loss due to multiple small pox outbreaks and a flu epidemic (Trimble, 1989) which resulted in the number of villages being reduced due to the conglomeration of the survivors into a handful of larger villages. This extreme stress placed upon the Arikara resulted in many changes to their society and way of life (Rogers, 1990).

Evidence from this research suggests that the diachronic changes experienced by the Arikara may have also affected post marital residence practices. Changing from a practice of patrilocality with clan exogamy to matrilocality with village endogamy may have been an adaptive strategy employed to decrease mortality within the village. Hawkes et al. (1997) suggests that there are benefits to female relatives living together, such as increased survivorship of juveniles and fertility of adults. During times of extreme stress on the population, adjusting the living patterns may have served as an effective and expedient response to rapid social changes. Several aspects of Arikara society changed during this time and it is possible that the mode of post marital residence for the Arikara may have been altered as well; patterns of clan exogamy and village endogamy may hold true for later Arikara sites, but may not accurately reflect the practices of earlier sites. This may explain why evidence from earlier sites does not match the ethnohistoric account; further research into this matter is warranted to substantiate this postulate.

In past research, Sully E has stood out as having the most divergent morphology among the burial areas at Sully (McKeown, 2000; McKeown and Jantz, 2005; Agosto and McKeown, 2012). This is evident in only the females from Sully E in a plot of the Sully components along the first and second canonical from the CVA performed on just Sully; this can be seen in Figure I located in Appendix D. The separation of Sully E may be explained by the presence of bilateral asymmetry present in the crania from this burial area. Bilateral asymmetry is present to some degree in all the burial areas at Sully, but McKeown and Jantz (2005) identified higher levels in Sully E as compared to Sully A and D.

It has been suggested that some of the individuals from Sully E may be intrusive burials from other Northern and Central Plains groups. Jantz et al. (1981) found that some individuals from Sully E misclassified as Pawnee or Mandan in discriminant function analyses. This hypothesis gains support from the canonical analysis performed by Owsley and Jantz (1978) in respect to the females from Sully E displaying close similarity to the females from Murphy (25DK9), a Central Plains site dating to the Central Plains Tradition. It is possible that some of the morphological differences with Sully E stem from the presence of intrusive burials, but based on the levels of overlap between all individuals from Sully in the CVAs, the likelihood of this hypothesis for this sample is low.

Genetic influences from different geographic regions of Arikara territory may be responsible for the morphological variability present between Sully A, Sully D, and Sully E. Results from this analysis suggests a possible ancestral relationship between Sully and the late Mobridge component and the Bad River villages, as well as differential levels of admixture and marital migration between the individuals interred within Sully, Anton Rygh, Mobridge F2, and

the Bad River villages. Differences in the levels of admixture with outside villages may suggest that the burial areas at Sully are clan based.

The biological evidence appears to support a system of inter-village admixture and marital migration between Sully and the surrounding villages, but there is a cultural component that may lend support for partial village exogamy at Sully. The grave good frequencies between the males and females from Sully A, Sully D, and Sully E comprising the sample for this study also suggest differences between the groups. The most significant difference is between the quality, quantity, and type of grave goods between males and females; however, differences between the sexes do not necessarily support the idea of different cultural components between the two groups. Disparities within a sex based on burial area are more indicative of the presence of multiple cultural components.

The percentages of the type of grave goods associated with individuals in the Sully sample were calculated to discern whether or not cultural differences existed between the sexes of each burial area; quality of items was consistent throughout the sample, so it was not considered a dividing factor. Table 10 displays the type of item and percentage for each burial area based on sex for the individuals included in the sample for this study.

Table 10. Proportion of Items Included in the Sully Cemetery Sample

| | Sully A Females | Sully D Females | Sully E Females | Sully A Males | Sully D Males | Sully E Males |
|--------------------------------------|-----------------|-----------------|-----------------|---------------|---------------|---------------|
| No Associated Items | 12.50% | 27% | 60% | 46% | 30% | 35% |
| Wood Covering | 63% | | 20% | 15% | | |
| Utilitarian Items Only | 25% | 27% | 10% | 8% | | |
| Adornment Items Only | | 9% | | 15% | 30% | 24% |
| Both Adornment and Utilitarian Items | | | | 8% | 20% | 12% |
| Animal Hide Robe | | 27% | | | 30% | |
| Ochre | | 9% | | 15% | | 6% |
| Pipes | | | | 15% | 10% | |
| Pottery | | | | | 10% | 6% |
| Animal Bones or Claws | | | 10% | 8% | | 29% |
| Seeds | | 9% | | | | |

There are a couple of disparities between the percentages of grave goods for both the males and females that may suggest the presence of multiple cultural components. The difference between the males are not large and consist of the presence of ochre and unworked animal bones in Sully A and Sully E, pottery at Sully D and Sully E, catlinite pipes at Sully A and Sully D, and robe remnants present at Sully D. Differences in the distributions of goods between the females appear to be more definitive than those of the males. Between the females, Sully E has a large proportion of individuals (60%) without associated grave items and it was the only burial area among the female to have unworked animal bones. Sixty-three percent of the burials within Sully A had a wood covering, which is far greater than the other two burial areas. The biggest difference between the females is with those interred at Sully D; this was the only burial area to have adornment items, animal robes, ochre, or seeds included in the graves of females.

The differences present between the males are not as disparate as those between females, and may not be as indicative of the presence of multiple cultural groups as the females. There are very different proportions and types of grave goods between the females of each of the three burial areas and this may be indicative of varying cultural practices. This would be supportive of idea of patrilocality at Sully with the importation of females from outside villages and compounds upon the morphological evidence. It should be noted that the proportion of grave goods within this sample may be significantly affected by the small sample sizes for the sexes at each burial and may not accurately represent the whole of the population. It is also possible that the lack of certain types or quantities of grave goods within the female

burials may be due to the inclusion of organic goods that did not survive the archaeological record.

Possible Sources of Error

This analysis contains several possible sources of error that could affect both the outcome of the analyses and their interpretation; all sources of error in this analysis are common and most of them insignificant. Error can be contributed to data collection techniques, equipment, human error, landmark choice and small sample sizes. Effort has been made to minimize any affects these sources may have and consider them in the interpretation.

There are a few inherent sources of error in the data collection process that may affect the results of this analysis; the use of standard definitions for cranial landmarks and the precise nature of the digitizer work to minimize such error. Accuracy of the digitizer is within .23mm and can be accounted for by the movement of the arm during data collection (Ousley and McKeown, 2001). Precision in placement of the point of the digitizer, interpretations of landmark definitions and their placement on the cranium account for the sources of human error; more arbitrary landmarks increase the level of error. Data collection by a single individual aided in the reduction of human error for this data set.

Landmark choice and interpretation of their definitions is a crucial aspect to morphometrics and the interpretation of the statistical analyses. Each landmark type is associated with different levels of error: Type 1 landmarks have precise definitions and are subject to little or no error, whereas Type 3 landmarks have more ambiguous definitions and are subject to high levels of error based on researcher interpretation. Error associated with

landmark choice was kept to a minimum in this analysis by the utilization of mainly Type 1 landmarks and excluding any Type 3 landmarks.

Error within this analysis may also be caused by small sample sizes. Sampling bias is more common in small samples because they are more likely to not accurately represent the population from which they originate; the range of variation within the population may not be captured by just a few individuals. This is a common issue with skeletal collections mainly because of preservation issues. Unfortunately, this is a factor beyond the control of the investigator, but it is important to consider during interpretations.

Reducing sources of error is important to all analyses because the outcome of the analysis can be greatly affected by the inherent error in the data. High levels of error both within the data and the samples can convolute the results of the analyses as well as the interpretations of those results. It is important to consider all sources of error in an analysis and take steps to minimize their effect on the outcome of the study.

Overall, it is apparent that the occupants of the Sully site did not practice strict village endogamy and most likely had close relations with other La Roche Arikara villages. This study can also support amalgamating Sully into a single sample in future analyses. Evidence for the practice of village exogamy at Sully is contradictory to past accounts of post marital residency practices for the Arikara. Exogamy on the village level may obscure any post marital residency patterns that may exist between clans within the village. Although the tests of homogeneity show that the differences in variation between males and females at Sully are not significant, the results from this study indicate that there are meaningful patterns to the variation between the sexes. The patterns identified, in conjunction with the archaeological evidence, lend

support to contemporaneity of the Sully burial areas; there has been no evidence revealed in this study that would suggest temporal spacing of the cemeteries and instead revealed that the tests of homogeneity within the burials areas most likely failed because of issues with the presumed pattern of post marital residency. Further implications of these findings suggest that a deeper study of Arikara kinship structure is needed.

Chapter 6: Conclusion

The purpose of this research was to use the theoretical framework of population genetics to identify factors contributing to the morphological variability between three of the Sully burial areas. The craniofacial morphology was assessed using a combination of geometric morphometry and standard statistical procedures. Utilization of three dimensional coordinate data allowed for the preservation of all relationships between the cranial landmarks and extracted size as a variable so that shape differences could be the concentration of the analysis. Removing size from the data eliminated this confounding factor when combining males and females and allowed for the strict analysis of shape to be performed. The fitted coordinates from the geometric morphometric analysis were subjected to a series of multivariate statistical analyses to provide a quantitative approach to interpret the underlying factors affecting cranial morphology.

Based on the results of this study, the research hypothesis proposing matrilineal post marital residence for the burials areas was rejected; the null hypothesis was accepted, indicating that the levels of morphological variability between the sexes is not statistically significant. Additional analyses suggest that the expected pattern of clan exogamy and village endogamy were not strictly adhered to and that individuals at Sully had relationships that expanded beyond the village to include the late Mobridge occupation, the Bad River villages, and the females at Anton Rygh.

The degree of similarity between Sully and the La Roche villages is suggestive of an ancestral relationship between these groups of people, with individuals from Sully acting as

part of the founding population for the other villages. Although there may have been separation of these individuals from Sully, it should not be expected that all ties between the two groups would have been severed; thus it is possible that mate exchange took place between the groups to maintain kinship ties and consequently retain morphological similarity between the groups through time.

The morphological similarity between the females from Sully A and those from Anton Rygh is another line of evidence from this study that supports the practice of village exogamy at Sully. The varying degrees of morphological similarity between the sexes from the different Sully burial areas suggests that the Arikara of the Extended Coalescent may have participated in a complex system of mate exchange between villages. This evidence suggests that marital migration between villages may be the factor responsible for the significantly different cranial morphologies between Sully A, Sully D, and Sully E and not their temporal separation. Additionally evidence was found that suggested the presence of low levels of admixture between all individuals at Sully. The distribution of grave goods within the sexes also acts to support the presence of varying cultural components within the burial areas. Overall, it appears that the burial areas at Sully may represent contemporaneous, clan based burials from a society that participated in inter-village marital migration.

Additionally this research has been able to show that the level of morphological variability present within the Sully site is no greater than that of other Arikara villages. This finding suggests that future studies examining the Arikara can consider all individuals from Sully a cohesive sample. Separation of individuals by burial area is only necessary for intra-site analyses, but not necessary for inter-site investigations of the Arikara.

The results from this study have been able to provide insight into the social organization and kinship structure of the early Arikara at the Sully site through the application of microevolutionary processes. This research was also able to demonstrate the effects of admixture on craniofacial morphology and how it can shape population structure. Unexpectedly, this research revealed discrepancies between the ethnohistoric accounts of post marital residency practices for the Arikara and the biological evidence. This finding demonstrates the utility of craniometric analyses in revealing the population history of non-extant or disenfranchised populations.

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Appendix A: Coalescent Tradition

Phases and Dates Associated with the Coalescent Tradition from McKeown (2000): p23.

Coalescent Tradition

Initial Coalescent Variant (1300 – 1600 AD)

Extended Coalescent Variant (1400/1450 – 1650 AD)

Shannon Phase

Le Compte Phase

La Roche Phase

Akaska Phase

Post-Contact Coalescent Tradition (1650 – 1862 AD)

Felicia (1675 – 1700 AD)

Talking Crow (1650 – 1700 AD)

Bad River (1650 – 1800 AD)

Le Beau (1650 – 1785 AD)

Knife River

Willows

Minnetaree

Roadmaker

Four Bears

Historic (Euro-American) Period

Appendix B: Data Collection Protocol

The following is an excerpt of the data collection protocol from McKeown (2000, pp. 68-69). During the time of the data observation by McKeown, the Arikara collections at the University of Tennessee, Knoxville had been inventoried and the Arikara of the Three Affiliated Tribes had been notified in compliance with NAGPRA regulations. The collections at the Smithsonian Institution are governed by a separate agreement between the Institution and federally recognized tribes and were in the initial process of being evaluated by Smithsonian staff.

“All observable Cartesian (x, y, z) coordinates were collected from each cranium in the sample via a MivroScribe-3DX, three dimensional digitizer, connected to a laptop computer. Observation of landmarks on crania occurred according to two different collection protocols. The first collection method was employed early in the data collection process and was used for all crania housed at the Smithsonian Institute. The second collection protocol was implemented later in the collection process and was utilized for all crania housed at the University of Tennessee, Knoxville.

The first data collection protocol involved collecting landmarks from a single cranium as two separate configurations. Each configuration was saved as a page in an Excel spreadsheet and each case was saved as an Excel spreadsheet file. A series of landmarks was observed on the superior aspect of a cranium secured to a stable surface with modeling clay. A smaller, second series of landmarks was collected from the inferior aspect of the cranium while it was secured with modeling clay to a stable surface in an inverted position...At least 3 and as many as 7 landmarks were observed from both the superior and inferior perspectives. These landmark coordinates served as ‘matching points’ for the rotational procedure that fitted the two configurations together. This program, known as GIT (Get It Together) written by Lyle Konigsberg, uses a Procrustes procedure to translate and rotate the two configurations until the sum of the squared distances between ‘matching points’ is minimized. Thus the two configurations are brought together and the landmarks are output as a single configuration.

The second data collection protocol in this research used a vertical metal stand with a perpendicular metal ring to elevate the cranium allowing access to all aspects of the form during landmark observation...The three dimensional coordinate data collection program, 3Skull, written by Stephen Ousley, generates two Paradox databases, one containing the x, y, and z landmark data and a second with the traditional Howells (1973) craniometric data set. This data collection procedure produces a set of three dimensional landmarks comprising a single configuration for each individual.”

Appendix C: Landmark Definitions

Alare (L/R): The most laterally positioned point on the anterior margin of the nasal aperture (Moore-Jansen et al., 1994, p45).

Bregma: The posterior border of the frontal bone in the median plane. Normally this is the meeting point of the coronal and sagittal sutures (Howells, 1973, p167).

Dacryon (L/R): The apex of the lacrimal fossa, as it impinges on the frontal bone (Howells, 1973, p167).

Frontomalare Anterior (L/R): The most anterior point on the fronto-malare suture (Howells, 1973, p168).

Frontomalare temporale (L/R): The point where the frontozygomatic suture crosses the temporal line (or outer orbital rim) (White et al., 2012, p58).

Frontotemporale (L/R): The point where the temporal line reaches its most anteromedial position on the frontal (White et al., 2012, p58).

Nasion: The intersection of the fronto-nasal suture and the median plane (Howells, 1973, p169).

Pterion (L/R): The intersection of the frontal, temporal, and parietal, and sphenoid meet on the side of the vault (White et al., 2012).

Zygomatic Root (auriculare) (L/R): A point on the lateral aspect of the root of the zygomatic process at the deepest incurvature (Moore-Jansen et al., 1994, p45).

Zygomaxillare Anterior (L/R): The intersection of the zygomaxillary suture and the limit of the attachment of the masseter muscle, of the facial surface (Howells, 1973, p170).

Zygoorbitale (L/R): The intersection of the orbital margin and the zygomaxillary suture (Howells, 1973, p170).

Appendix D: Additional CVA Graphics

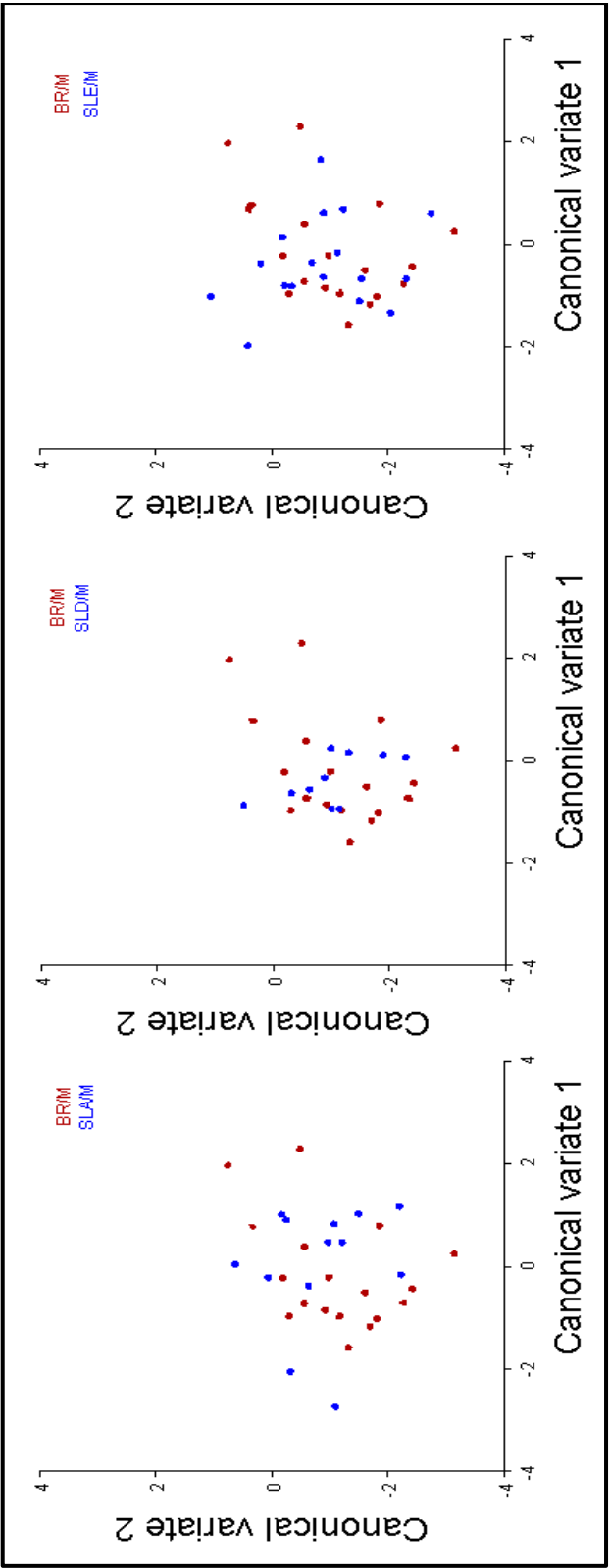


Figure A. CV1 vs. CV2 plot of Bad River and Sully males isolated by burial area

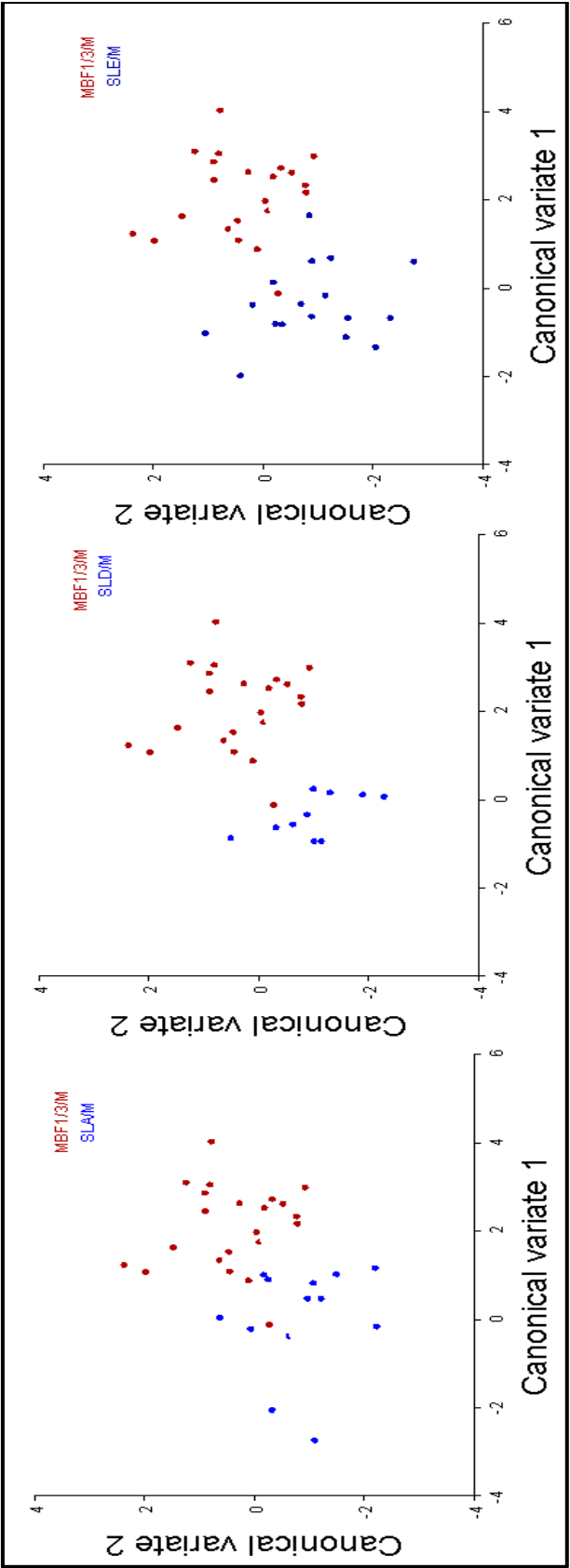


Figure B. CV1 vs. CV2 plot of Mobridge F1/3 and Sully males isolated by burial area

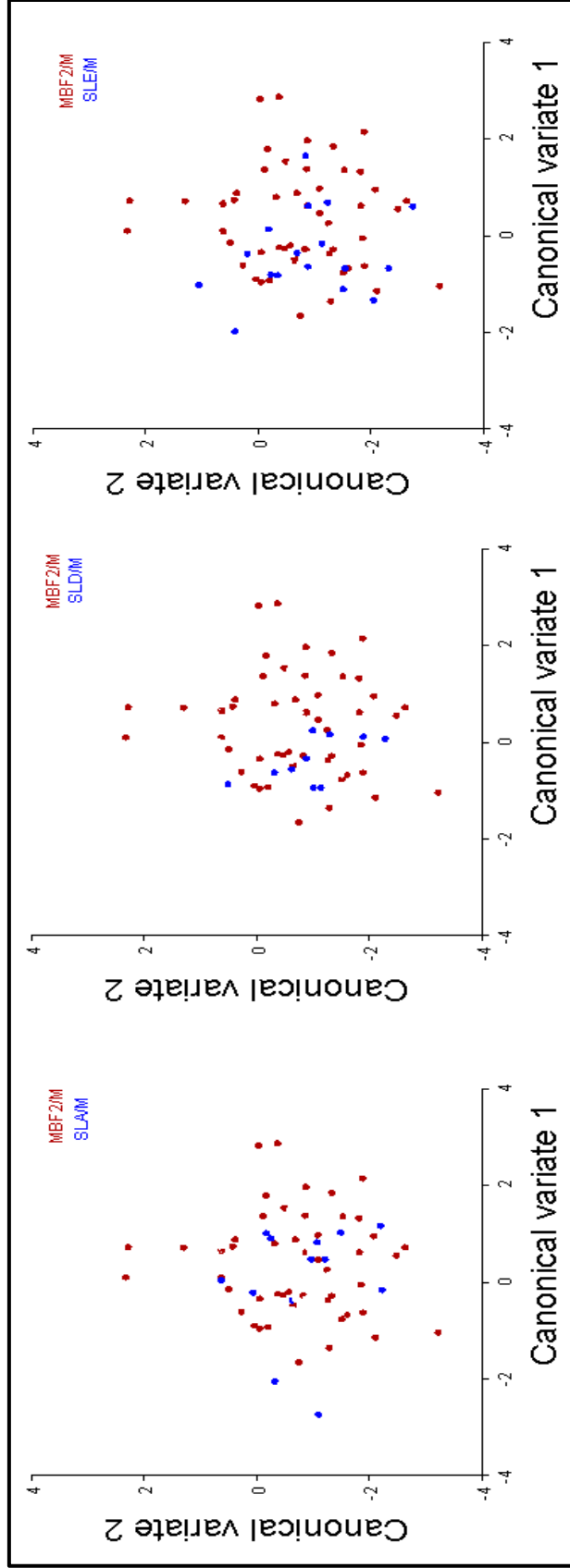


Figure C. CV1 vs. CV2 plot of Mobridge F2 and Sully males isolated by burial area

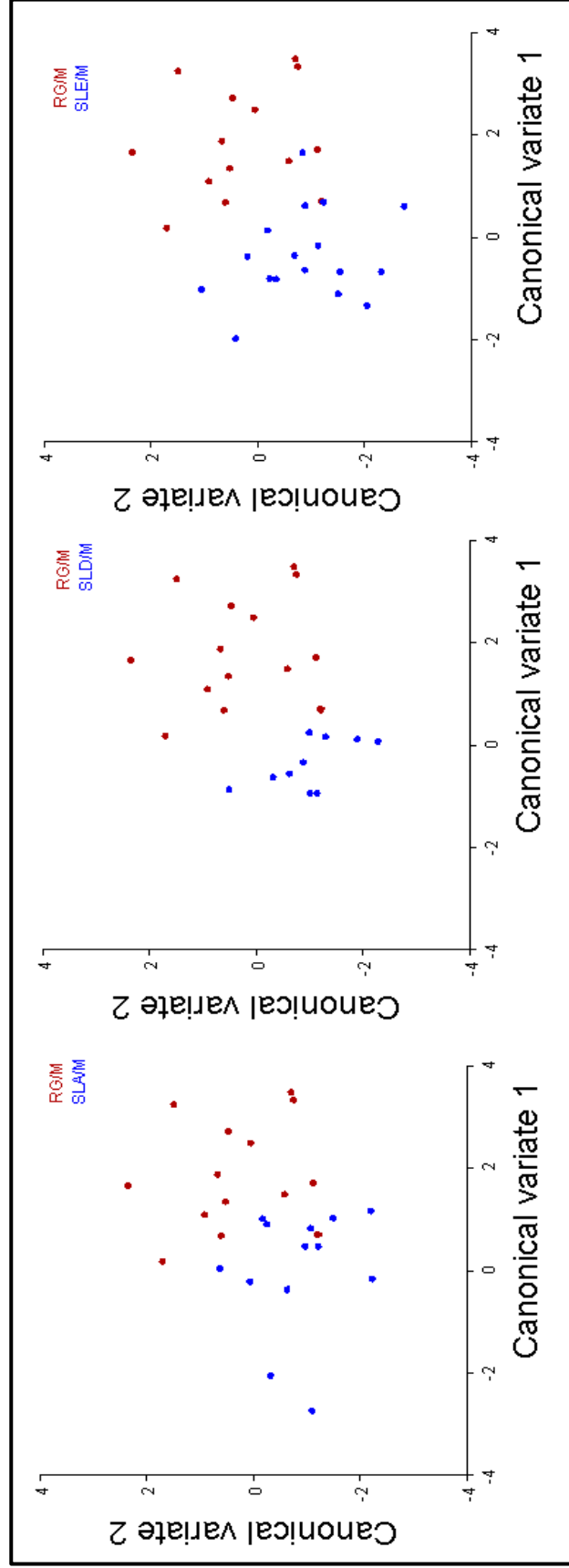


Figure D. CV1 vs. CV2 plot of Anton Rygh and Sully males isolated by burial area

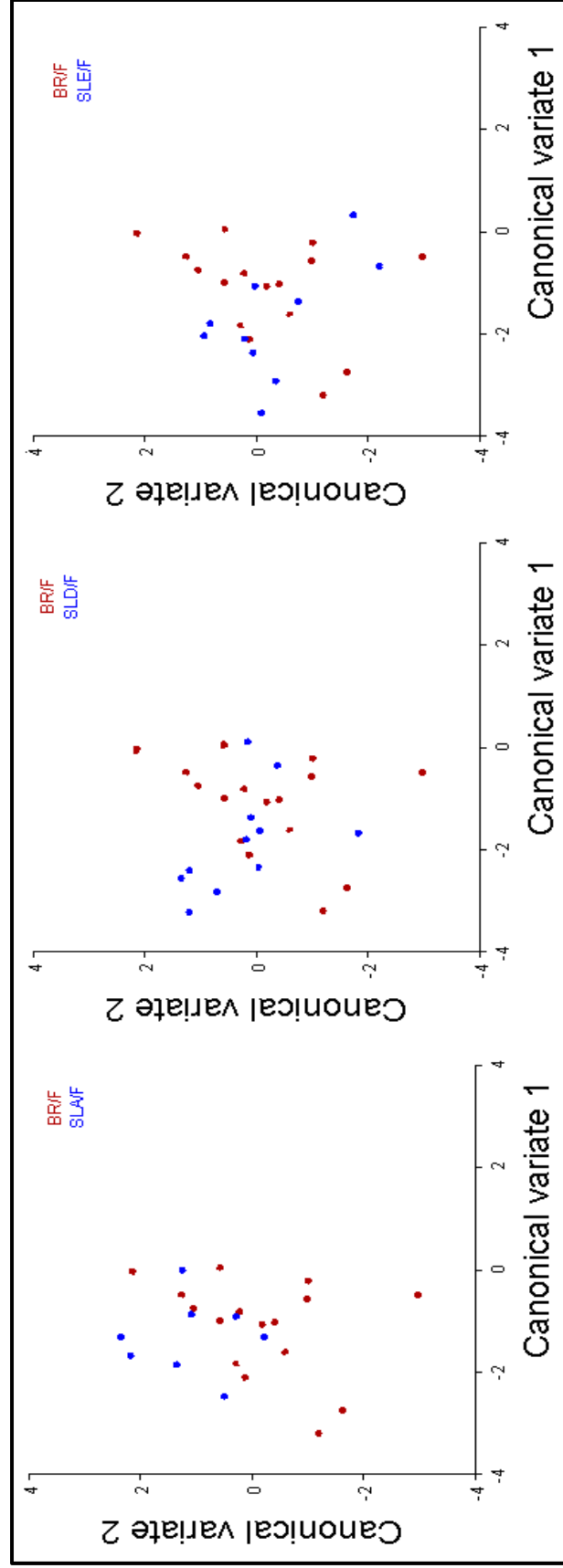


Figure E. CV1 vs. CV2 plot of Bad River and Sully females isolated by burial area

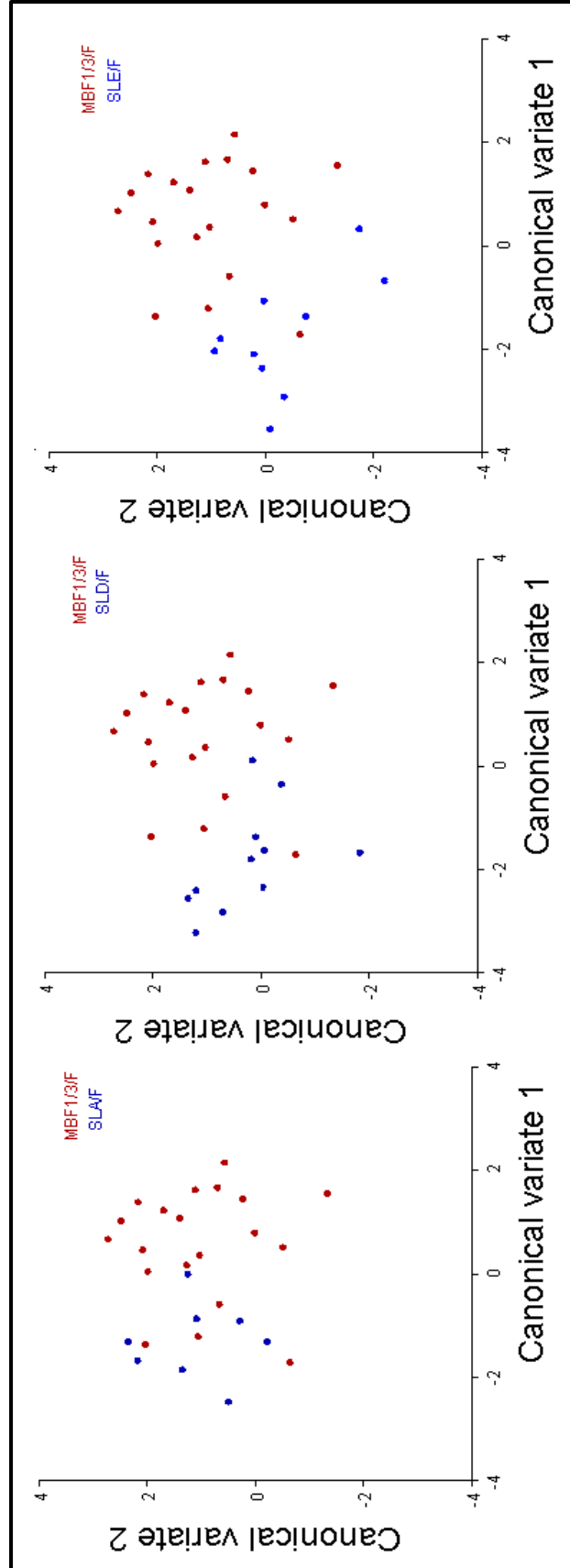


Figure F. CV1 vs. CV2 plot of Mobridge F1/3 and Sully females isolated by burial area

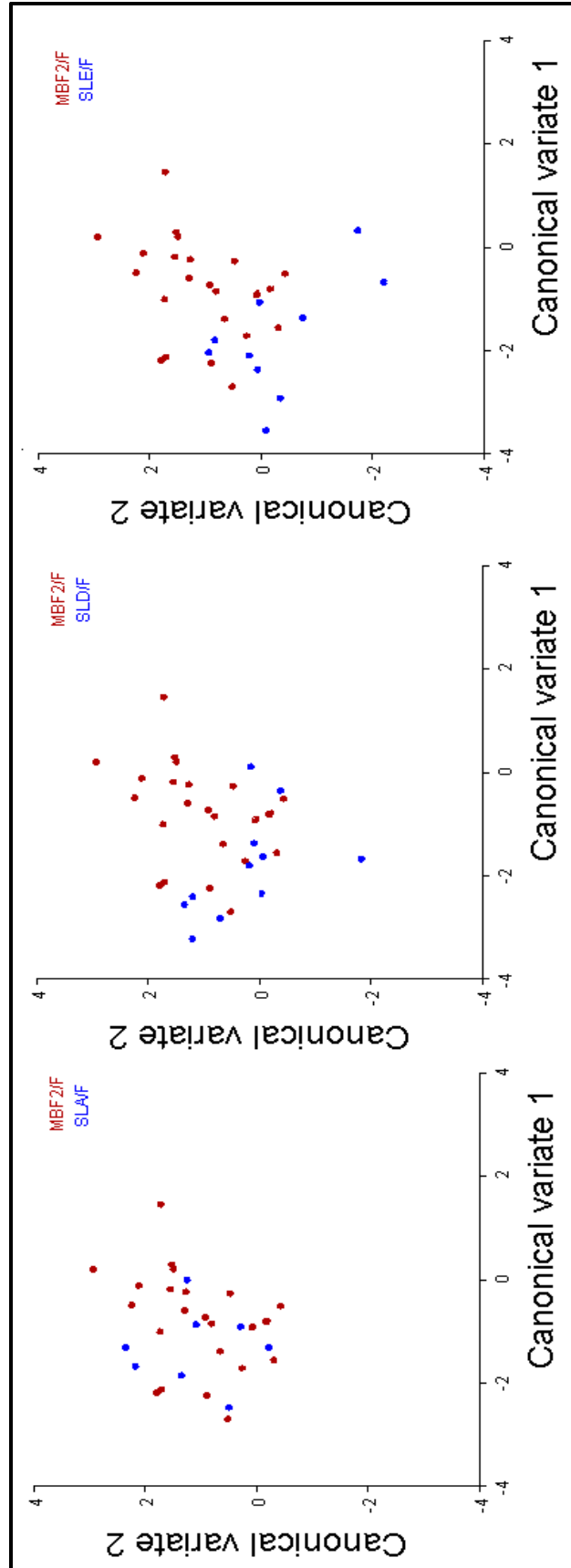


Figure G. CV1 vs. CV2 plot of Mobridge F2 and Sully females isolated by burial area

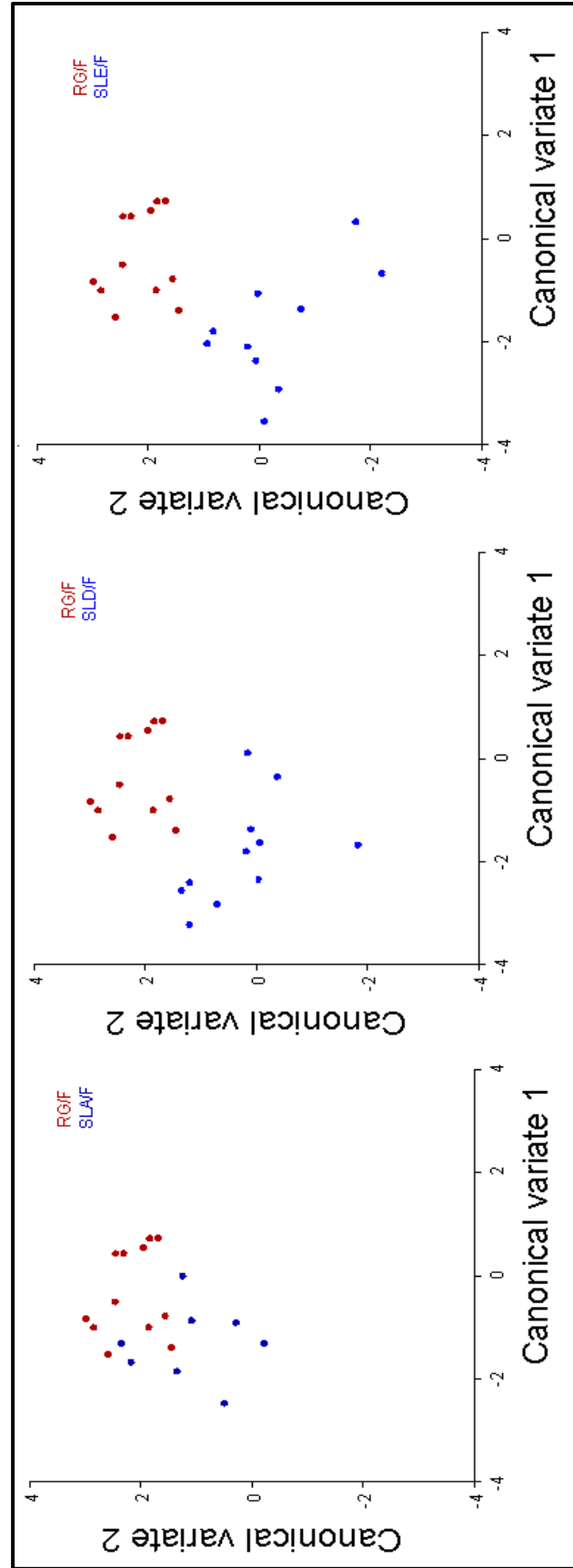


Figure H. CV1 vs. CV2 plot of Anton Rygh and Sully females isolated by burial area

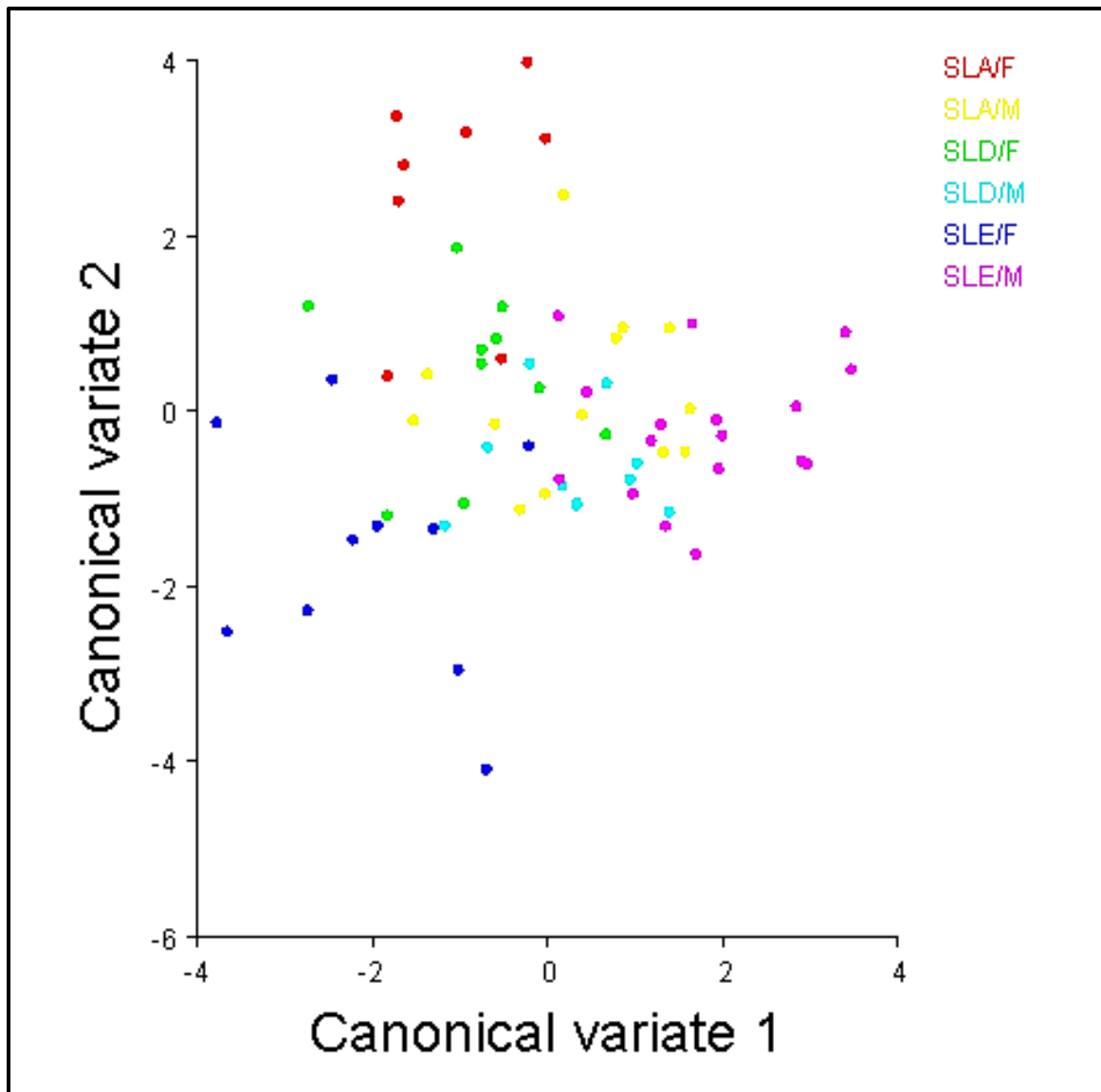


Figure I. CV1 vs. CV2 plot of males and females from Sully, separated by burial area